The Effect of Recommended Sharpening Characteristics on Skating Speed

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Abstract

The purpose of the study was to investigate the effect of combining recommended blade sharpening characteristics; namely, radius of contour, radius of hollow and pitch on skating speed in ice hockey players. An operational definition for recommended sharpening characteristics was derived from previous research, current industry practices and pilot work. Males, currently competing at the U16 (n = 21), U18 (n = 10), and Minor Midget AAA (n = 9) levels of competitive ice hockey were recruited to participate. Players completed a battery of eight on-ice skating drills representing skating skills typically used in game situations while skating on two blade sharpening conditions: (i) the player's current sharpening characteristics and (ii) the recommended sharpening characteristics. Movement initiation time (T1; s) and total skating time (TT; s) were measured for each drill. Composite scores were calculated as the sum of times across seven of the eight drills for T1 (s) and TT (s). Two-tailed paired samples t-tests were conducted to determine if significant differences existed in T1 (s) and TT (s) between conditions. Significantly faster times were revealed for the recommended sharpening condition on 4 of the 8 measured T1's (s/kg), on 2 of the 8 measured TT's (s/kg), and on both composite T1 and TT scores ($p < .05$). Data was then grouped in three ways for further analysis; by the number of sharpening characteristics adjusted (1, 2, or 3), by position (forward & defense), and by player weight (≤81.6 kg & >81.6 kg). When grouped by the number of sharpening characteristics adjusted, results revealed no significant differences when one or all three characteristics were adjusted. When two characteristics were adjusted significant differences were observed in 2 of the 8 T1's (s/kg) and TT's (s/kg) and in composite T1 and TT scores. When results were grouped by position or player weight, mixed results were revealed; meaning significant differences were revealed only on select skating drills that varied by group. All significant differences revealed faster times for the recommended sharpening condition. The results revealed may be indicative of the complex relationship between sharpening characteristics and performance in various on-ice skating skills.

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Introduction

Skate sharpening is an essential practice in the preparation and maintenance of skate blades and is employed routinely to enhance skating performance. The purpose of the blade shaping and sharpening process is to apply or alter three sharpening characteristics: radius of contour (ROC), radius of hollow (ROH), and pitch. Broadbent (1985) has provided operational definitions for the skate sharpening characteristics and a working knowledge of the blade-ice interaction. Radius of contour (ROC) refers to the longitudinal curvature of the blade and determines the amount of blade that is in contact with the ice. A longer contour allows for more blade-ice contact and has the potential to increase stability and skating speed, whereas a shorter contour provides less blade-ice contact and has the potential to increase agility. Radius of hollow (ROH) refers to the depth of the groove on the base of the blade and determines how the blade penetrates the ice. The amount of blade-ice penetration is also suggested to influence the glide and stopping capabilities of the blade. A more shallow hollow produces a smaller bite angle, creating less ice penetration and allowing for increased glide capability but reduced stopping ability. Whereas, a deeper hollow produces a larger bite angle, causing the blade to penetrate into the ice further and allowing for improved stopping ability but reduced glide capability. Pitch, also referred to as lie, is defined by the position of the blade's apex and has the potential to influence the player's balance point on the blade. A neutral pitch is created when the apex and the balance point are positioned at the blade center. Moving the apex backward from blade center causes the balance point to shift forward from blade center creating a forward pitch. Moving the apex forward of blade center shifts the balance point backward from blade center creating a backwards pitch. Edge levelness refers to the height of the inside and outside blade edges relative to one another and is often used as a control measure to verify sharpening quality. Unlevelled edges are deemed undesirable and are suggested to impair skating performance and increase the risk of lower limb injury (Broadbent, 1988; Lockwood & Frost, 2009), whereas level edges or edges of equal height are a desired outcome of the sharpening process.

Research investigating the effects of sharpening characteristics on skating performance has focused predominantly on the isolated effects of ROC (Lockwood & McKenzie, 2012; Lockwood & Winchester, 2004; McKenzie, 2012) and ROH (Federolf & Redmond, 2010; Winchester, 2007). Relationships between sharpening characteristic (ROC and ROH) and a player's weight has suggested that heavier players may benefit from longer contours and more shallow hollows, whereas lighter players may benefit from relatively shorter contours and deeper hollows (Lockwood & Winchester, 2004). More specifically, players achieve higher aerobic endurance and are able to maintain a greater skating intensity when ROC and ROH are selected based upon a player's weight (Lockwood & Winchester, 2004). When considering the isolated effects of ROC, combined contours consisting of more than one contour along the length of the blade have the potential to provide significant improvements in skating speed when compared to single radius contours (Lockwood & McKenzie, 2012). Furthermore, experienced players seem to prefer a combined or double contour consisting of a shorter radius from blade center forward and a longer radius from blade center back, as opposed to a traditional single contour (Lockwood & McKenzie, 2012). Research conducted on ROH has revealed that a deeper hollow has the potential to decrease stopping distance and time when compared to a more shallow hollow (Gagnon & Dore, 1983; Winchester, 2007).

Conversely, extremely deep hollows, 3.18 mm (1/8 in.) or approximately one quarter of the ROH's traditionally applied, have the potential to impair skating speed (Federolf & Redmond, 2010). There is currently little empirical evidence to support the effect of pitch on on-ice skating speed. However, research investigating the position of the center of mass (COM) of elite sprinters in the starting blocks has shown improvements in start times when the COM is moved forward, or what is referred to as forward pitch (Slawinski et al., 2010). Therefore, it would seem reasonable that a forward pitch on skate blades could also enhance the initiation of movement and acceleration.

Consolidating knowledge from research on isolated sharpening characteristics and current industry practices has provided a theoretical framework that may suggest how ROC, ROH, and pitch settings can be best selected based upon player weight, position, and preferences. That said, the theoretical framework and accepted practices have yet to be assessed with regards to the cumulative effect of adjusting or customizing all three blade sharpening characteristics on skating speed. Therefore, the purpose of the study was to investigate the effect of combining recommended blade sharpening characteristics; namely ROC, ROH, and pitch on skating speed in ice hockey players.

Literature Review

2.1 Skate Blades

Skate blades, commonly referred to as runners, facilitate a skater's interaction with the ice surface and have the potential to influence skating performance (Federolf & Nigg, 2012; Federolf & Redmond, 2010; Lockwood & Winchester, 2004; McKenzie, 2012; Winchester, 2007). The design and construction of modern skate blades vary in terms of material properties and blade geometry. Once purchased and installed on the boot, a variety of sharpening characteristics can be applied to the blade, influencing the blade-ice interaction.

2.1.1 Material properties.

Originally constructed out of animal bone and used for transportation across frozen surfaces, skate blades have evolved significantly over the past four millennia (Kühelmann & Zidarov, 2003). Today, skate blades are commonly manufactured using stainless steel due to its desirable properties of durability and corrosion resistance, while remaining malleable enough to be easily sharpened (Donnelly, 2010). The use of alternate blade materials allowing for increased blade durability, elongate edge retention, and decreased friction has been investigated (Abkowitz, Abkowitz, Fisher, & Schwartz, 2004; Horkheimer, 2007). Materials such as titanium composites have been shown to offer increased durability and edge retention as well as significant weight reductions, up to 40%, when compared to standard stainless steel blades (Abkowitz, Abkowitz, Fisher, & Schwartz, 2004). Other material advancements consist of applying a coating to the surface of the blade. Applying a diamond-like carbon (DLC) coating can create a harder surface on the blade, thereby decreasing blade wear over time when compared to uncoated stainless steel blades (Horkheimer, 2007). A DLC coating also produces a low coefficient of friction between the skate blade and ice-surface (Horkheimer, 2007). Although research has suggested improvements in specific blade properties such as weight, durability, and frictional properties when alternative materials and coatings are used, empirical evidence to support the ability of material properties to significantly affect skating performance is limited.

2.1.2 Skate blade geometry.

The geometry of a skate blade can be defined by three standard blade dimensions: length, height, and width (Broadbent, 1983). Length refers to the longitudinal distance from the heel to the toe of the blade and is relative to the size of the skate. Height refers to the distance from the base of the blade where ice contact occurs to where the top of the blade inserts into the blade holder of the skate. Blade height varies by manufacturer and will decrease with each sharpening as metal is ground away from the base of the blade. Width, or blade thickness, is the distance from one edge of the blade to the other. Width is also subject to vary by manufacturer; however, blade widths of approximately 2.29 mm to 3.05 mm can be considered standard in the sport of ice-hockey (Broadbent, 1985).

Alterations made to skate blade design have been proposed in an attempt to improve on-ice skating performance. For example, a skate blade with a flared base increases the blade width at the point of ice contact and increases the relief angle (angle between the side of the blade and the ice surface) of the blade. Using a mechanical model to assess the gliding distance of flared blades and standard blades, it was determined that a flared blade design has the potential to reduce blade-ice friction (Federolf, Mills, & Nigg, 2008). Furthermore, results from an on-ice assessment of skating speed indicated that the flared blade design has the potential to produce faster skating times when compared to a standard blade (Federolf & Nigg, 2012).

2.1.3 Sharpening characteristics.

Skate sharpening is a process used in the maintenance of skate blades to apply or adjust three sharpening characteristics: radius of contour (ROC), radius of hollow (ROH), and pitch. Industry practice typically denotes each sharpening characteristics using the imperial measurement system, presenting ROC in feet (ft) and ROH and pitch in inches (in.). Radius of contour (ROC), commonly referred to as blade profile, represents the longitudinal curvature of the blade (*Figure 1)*. Gagnon and Dore (1983) identified three radii that are present on the standard contoured skate blade. The center radius is typically applied to the section of blade between the two stanchions of the blade holder and comprises the majority of the skate blade contour. Two smaller radii are located in front of and behind the center contour and continue through to the toe and heel of the blade. The center radius of a skate blade is the primary area of blade-ice interaction and is the radius described by the ROC setting. It has been generally accepted that longer ROCs increase blade-ice contact providing improved stability and enhanced skating speed. A shorter ROC will provide less blade-ice contact, thereby, increasing the maneuverability of the blade and being suited for quick turns and pivots (Lockwood & McKenzie, 2012). Currently, ROCs applied for hockey players are often a single, double, triple, or quadruple contour. Single contours on hockey skate blades are typically applied in the range of 2.13 m - 3.05 m (7 ft - 10 ft) radii (Lockwood & Winchester, 2004). Double contours consist of two different radii that are applied along the length of the blade, generally a shorter radius from blade center forwards and a longer radius from blade center backwards. Triple contours use two different radii, similar to double contours that are blended together with a flat section of the blade that transitions between the apexes of each radius. Quadruple contours consist of four contours applied along the length of the blade and are similar to double contours in that the four contours are not blended together with flat sections of the blade. Combined contours typically consist of shorter radii being placed forward of blade center in order to coordinate with a player's weight positioning while executing skating skills such as stops, starts, turns, and pivots. Whereas, longer radii are often placed backwards of blade center in order to coordinate with a player's weight positioning during linear skating (Lockwood & McKenzie, 2012).

Radius of hollow (ROH) refers to the depth of the groove that is applied to the base of a skate blade through the sharpening process (Broadbent, 1983) (*Figure 2*). If a smaller radius is shaped on to the grinding stone that is used to apply the ROH to the skate blade, a deeper hollow will be created. If a larger radius is shaped on to the grinding stone, a more shallow hollow will be created. Traditionally, the ROH refers to a semicircular hollow on the base of the blade that creates the inside and outside edges and dictates the bite angle of the blade. Deeper ROHs will increase the bite angle, allowing the blade to penetrate further into the ice and, thereby, reduce glide capabilities and increase stopping ability. A more shallow ROH will decrease the bite angle, causing the blade to penetrate the ice less and, thereby, increase glide capabilities and reduce stopping ability (Broadbent, 1983).

Pitch, also often referred to as lie, is used to describe the angle of the skate relative to the ice surface (Broadbent, 1983) (*Figure 3*). The pitch of the blade is dependent upon the location of the apex or balance point of the blade. Pitch settings are traditionally rated as plus (+) or minus (-) a certain number, with the sign representing the direction of pitch and the number indicating the shift in apex in inches from blade center. A plus (+) setting indicates a forward pitch and a minus (–) setting indicates a backwards pitch. These settings are in reference to blade center, or the physical center of the blade; however, certain sharpening practices use a designation of pitch center (PC), a setting that is equivalent to a +1 setting from blade center. When the apex is positioned at blade center, equal parts of the blade's contact zone (the section of blade in contact with the ice while in a balanced position) exist in front of and behind the blade's apex; this is considered a neutral pitch. Shifting the blade's apex will theoretically cause a corresponding shift in the player's center of mass (COM) or balance point on the skate blade in the opposite direction of the apex shift (Broadbent, 1985) (Appendix A). Therefore, when the apex is shifted backwards from blade center, a forward pitch is created and when the apex is shifted forwards from blade center, a backwards pitch is created. A shift of the apex and the resulting shift in balance point can also be directly related to a change in lie, or the angle of the skate relative to the ice (Appendix A). Mathematical models identified by Broadbent (1985) and depicted in Appendix A, illustrate the relationship between skate blade sharpening characteristics and how the shaping of the blade alters pitch and influences COM positioning and the lie of the skate relative to the ice.

Edge levelness refers to the height of the inside and outside edges with respect to one another and is often used as a control measure to determine sharpening quality (*Figure 4*). Typically, levelled edges are sought to be maintained as opposed to applied or adjusted through the sharpening process. Edge levelness within $1/1000^{th}$ in. is considered the result of a quality sharpening whereas unlevelled edges, a difference in edge height greater than $1/1000^{th}$ in., are deemed undesirable and the result of a low quality sharpening. Broadbent (1988) suggested that edges as unlevelled as 0.0056 in. can vary the bite angle of a blade's edges by 66% when compared to level edges. Moreover, it is suggested that unlevelled edges not only have the potential to hinder skating ability, but also to increase the risk of lower limb injury (Broadbent, 1988; Lockwood & Frost, 2009).

2.2 On-Ice Performance Measures

Skating speed is often considered an important contributing factor to in game performance and is a vital attribute for players to compete at an elite level (Hansen & Reed, 1979). Extensive work has been conducted to investigate off-ice performance measures that can be used to predict on-ice skating speed (Behm, Wahl, Button, Power, & Anderson, 2005; Farlinger, Kruisselbring, & Fowles, 2007; Fernandez, Geithner, Haia, & Bracko, 2008; Krause et al., 2012; Mascaro, Seaver, & Swanson, 1992). However, limited research has investigated the use of on-ice assessments to determine skating ability. Current on-ice assessments such as the Reed repeat sprint skate test, the Repeat Ice Skating Test (RIST), and the Faught Aerobic Skate Test (FAST), are typically used to predict physiological performance measures such as peak power, relative peak power and aerobic power, and use these predictions to estimate on-ice performance potential (Petrella, Montelpare, Nystrom, Plyley, & Faught, 2007; Power, Faught, Przysucha, McPherson, & Monteplare, 2012). These tests typically use bouts of linear skating and do not associate with many skating skills and maneuvers essential to in-game performance. Although skating speed is considered an important contributing factor to on-ice performance, skating in a game situation is often characterized by short periods of high intensity output and impulse forces associated with maneuvers such as acceleration, stops, starts, turns, and pivots (Behm, Wahl, Button, Power, & Anderson, 2005). Limited research has investigated the functionality of an on-ice agility test. However, Nightingale

(2015) demonstrated that the on-ice Pro Agility Test (PAT) has strong test-retest reliability and correlates with years of hockey playing experience.

Studies investigating the effects of equipment based alterations on on-ice skating performance have used assessments composed of on-ice skating drills designed to represent skating skills and maneuvers used in game situations; forwards skating, backwards skating, stops, starts, turns and pivots (Federolf & Nigg, 2012; Lockwood & Winchester, 2004; McKenzie, 2012). Timing light systems are traditionally used in accordance with the skating drills to measure interval or total skating times (s) that are interpreted as an indication of the player's skating ability. Although certain equipment and skating skills are often used to assess on-ice skating performance, there is currently no standardized on-ice assessment to determine a player's skating speed or ability.

2.3 Skate Sharpening Practices and On-Ice Performance

It is common practice within the discipline of skate sharpening to alter blade characteristics, namely ROC, ROH and pitch, based upon player size, position, experience and personal preferences. Radius of contour (ROC) and ROH are typically selected based on player weight, with players over 81.6 kg (180 lbs) being placed on a ROC of 3.05 m (10 ft) or greater and a ROH of 15.9 mm (5/8 in.). Players weighing 81.6 kg (180 lbs) or less are typically placed on a ROC of 2.74 m (9 ft) and a ROH of 12.7 mm (1/2 in.). Conceptually, for lighter players, their body weight will cause the skate blades to sink into the ice less, therefore a deeper hollow is applied to permit sufficient blade-ice penetration and provide the player with "grip" on the ice. More shallow hollows may be used for relatively heavier players as their body weight will cause the blade to sink into the ice further, thus providing the necessary blade-ice penetration while maintaining a more shallow hollow. Pitch selection is traditionally based upon player position and skating tendencies. Typically, forward pitch settings are used for defense players or for forwards players that display increased tendencies for stops, starts and quick maneuvers. Backwards pitch settings are less commonly applied and are used to increase stability. Although these are industry accepted methods for selecting ROC, ROH and pitch for individual players, accounting for player preference or what the player feels comfortable skating on is also considered an important factor.

Current research has focused predominantly on the effects of adjusting individual sharpening characteristics, namely ROC and ROH, and their ability to independently influence skating performance. Research suggests a positive correlation exists between ROC length and player weight, supporting current practices within the skate sharpening industry (Lockwood & Winchester, 2004). When ROC is selected based upon player weight, with heavier players on longer contours and lighter players on shorter contours, players are able to skate at a given intensity for longer periods of time (Lockwood & Winchester, 2004). Research has also revealed the potential for combined radii blades to produce significant improvements in skating speed when compared to single contour blades (McKenzie, 2012). Specifically, a triple contour of 2.74 m - 5.08 cm - 3.05 m (9 ft - 2 in. - 10 ft) produced significantly faster times for linear skating and agility skating when compared to single contours. Furthermore, a triple contour of 2.74 m - 5.08 cm - 3.05 m (9 ft – 2 in. – 10 ft) produced significant improvements in acceleration and in agility and linear skating speeds when compared to a triple contour of 2.13 m - 5.08 cm - 3.96 m (7 ft - 2 in. - 13 ft) (McKenzie, 2012). Player preference was in agreement with the on-ice skating times, revealing that players preferred skating on combined contour blades when compared to single contour blades (Lockwood & McKenzie, 2012).

Research has also suggested a positive correlation exists between ROH and player weight, and further supports current industry practices (Lockwood & Winchester, 2004). When ROH is selected for players based on body weight, with heavier players skating on shallower hollows and lighter players skating on deeper hollows, players are able to skate at a greater intensity for longer periods of time (Lockwood & Winchester, 2004). Research conducted using a mechanical model to investigate the effect of ROH depth on stopping distance and time has revealed that a deeper ROH (13 mm; 1/2 in.) produces shorter stopping distances and faster stopping times when compared to a shallower ROH (38 mm; 1.5 in.) (Gagnon & Dore, 1983). However, the use of extremely deep ROHs, 3.18 mm (1/8 in.) or lower, can significantly reduce skating speed when compared to ROHs in the range of 9.53 mm - 22.23 mm (3/8 - 7/8 in.) (Federolf & Redmond, 2010). If ROH is within the range of 9.53 mm - 22.23 mm (3/8 in. - 7/8 in.) no significant difference in skating speed is observed (Federolf & Redmond, 2010). Current research conducted to investigate the effects ROH on skating performance has used a semicircular ROH (Federolf & Redmond, 2010; Gagnon & Dore, 1983; Lockwood & Winchester, 2004; Winchester, 2007). Recent developments in the application of ROH have seen several changes to the traditional semicircular hollow found on skate blades, including a flat based groove. There is however no empirical evidence to date to suggest that changing the shape of the hollow results in a performance advantage when compared to traditional semicircular hollow.

There is currently limited research investigating the effect of pitch on skating speed. However, research assessing the effect of COM positioning, relating to a forward pitch, on sprint starts has revealed that a more forward position of the COM correlates with improved start times (Schot & Knutzen, 1992; Slawinski et al., 2010). Results from Schot and Knutzen (1992) revealed that when the COM was positioned further forward, sprinters achieved greater initial impulse and an increased velocity in the horizontal direction after the first step. A forward COM position also led to more force being allocated to horizontal translation as opposed to vertical translation and resulted in increased acceleration (Schot & Knutzen, 1992). Findings from Slawinski et al. (2010) indicated that along with their COM being positioned approximately 5 cm further forwards in the blocks, elite sprinters produced higher velocities leading to better two-step sprint starts when compared to well-trained sprinters. Observations of an increase in forward lean, indicating a more forward COM position, during the acceleration phase of skating in both elite (Marino, 1983) and developmental age (McPherson, 2004) hockey players coincide with the findings of Schot and Knutzen (1992) and Slawinski et al. (2010). The ability to accelerate quickly and efficiently is essential in a variety of sports including ice hockey and COM positioning relating to a forward pitch has been shown to significantly affect this ability (Schot & Knutzen, 1992).

The research outlined above suggests the potential of ROC and ROH to independently affect skating performance and the potential of COM positioning related to a forward pitch to affect movement initiation (Federolf & Redmond, 2010; Lockwood & Winchester, 2004; McKenzie, 2012; Schot & Knutzen, 1992; Slawinski et al., 2010; Winchester, 2007). There is however a lack of research investigating the combined effect of ROC, ROH and pitch settings selected based upon individual player criteria, on skating performance.

2.4 Purpose

The purpose of the study was to investigate the effect of combining recommended blade sharpening characteristics; namely radius of contour, radius of hollow and pitch on skating speed in ice hockey players.

2.5 Research Questions

The primary research question stated was, can skate blade sharpening characteristics recommended based upon individual player criteria, weight and position, improve movement initiation and on-ice skating speed? The secondary research question stated was, did players reveal a preference for the recommended sharpening characteristics when compared to their current sharpening characteristics? Two additional research questions were stated. The first additional research question stated was, did the effects of the recommended sharpening condition vary based upon the number of sharpening characteristics adjusted? The second additional research question stated was, did the recommended sharpening characteristics selected based upon position promote faster skating times in position dependent skating skills?

2.6 Hypothesis

The primary hypotheses stated that, the movement initiation times (T1; s) and total skating times (TT; s) would decrease when skating on the recommended versus the current sharpening condition. The secondary hypothesis stated that players would prefer the recommended sharpening condition when compared to the current sharpening condition. The null hypotheses stated that, no significant differences would be revealed in movement initiation time (T1; s), total skating time (TT; s) or player preference between the current and recommended sharpening conditions.

$$H_1: T1_{CURRENT} = T1_{RECOMMENDED}$$

$$H_2: TT_{CURRENT} = TT_{RECOMMENDED}$$

$$H_3: \text{Player Preference}_{CURRENT} = \text{Player Preference}_{RECOMMENDED}$$

Additional hypotheses stated that players would experience a different influence, or change in skating times (ΔT: s), from the recommended sharpening characteristics based upon the number of characteristics adjusted between conditions and position. The additional null hypotheses stated that all players would experience the same influence, or change in skating times (ΔT; s), from the recommended sharpening characteristics regardless of the number of characteristics adjusted between conditions or position.

$$H_4: \Delta T_{1CHARACTERISTIC} = \Delta T_{2CHARATERISTICS} = \Delta T_{3CHARACTERISTICS}$$

$$H_5: \Delta T_{FORWARDS} = \Delta T_{DEFENSE}$$

2.7 Study Significance

The method of selecting recommended sharpening characteristics outlined within the study has the potential to become an accepted practice or industry standard, and assist practitioners in the skate sharpening discipline to select combinations of sharpening characteristics specific to individual players.

2.8 Limitations

Limitations were imposed by access to players, available ice times and funding. The study was conducted during the regular season; therefore, all on-ice assessments were held during the team's regularly scheduled practices. The number of ice sessions, or repeated trials, was limited to two per player. The current sharpening condition was used as a baseline for comparison; the recommended sharpening condition could not precede the current sharpening condition. Therefore, the trials could not be randomized. The familiarization period for the recommended sharpening condition was limited to 10 minutes. Player recruitment was limited to male hockey players between the ages of 14 and 18 years. Therefore, the results may not be generalized to other ages or female players.

Methods

3.1 Design

Current literature and industry practices were reviewed and pilot work was conducted to provide empirical evidence to create a framework for the selection of skate blade sharpening characteristics recommended based upon individual player criteria; weight and position. A quasi-experimental design was then used to compare and contrast movement initiation (T1; s) and total skating time (TT; s) collected during eight on-ice skating drills while skating on two different sharpening conditions. Sharpening conditions were defined as: (i) the current sharpening condition, consisting of the player's current skate blades and sharpening characteristics as applied for a game situation, and (ii) the recommended sharpening condition, consisting of the player's current skate blades sharpened with the recommended radius of contour (ROC), radius of hollow (ROH) and pitch settings.

3.3 Selecting Recommended Sharpening Characteristics

Recommended sharpening characteristics were selected based on a framework consisting of position of play and player weight as selection criteria. *Figure 6* illustrates the specific parameters used to select ROC, ROH and pitch. Radius of contour (ROC) was selected based upon player weight; as all players weighed less than 90.7 kg (200 lbs), a double contour of 2.74 m – 3.05 m (9 ft – 10 ft) was selected for all players' skate blades. Radius of hollow (ROH) was also selected based upon player weight; a ROH of 15.9 mm (5/8 in.) was applied for players that weighed over 81.6 kg (180 lbs) and a ROH of 12.7 mm (1/2 in.) was applied for players that weighed 81.6 kg (180 lbs) or less. Recommended pitch settings were determined based upon position of play and current industry practice. Players who were currently playing in the forward position were placed on a pitch center blade setting, whereas, players who were currently playing in the defense position were placed on a pitch center blade setting with an additional +1 pitch as set on a Blademaster CRM6 holder.

3.4 Participants

Forty male hockey players (N = 40) between the ages of 14 and 18 years, and currently playing at the U16 (n = 21; 15 ± 0.75 years), U18 (n = 10; 17 ± 0.52 years), or Minor Midget AAA (n = 9; 15 ± 0 years) levels were recruited to participate. Recruitment was limited to players in the positions of forward (n = 26) and defense (n = 14) and who were injury free at the time of the study. A power analysis (α = 0.05, β = 0.2) using Cohen's d for a moderate effect size (0.7) was used to calculate a sample size of 32 participants.

Players were informed that the study would require them to complete two on-ice assessments; the first while skating on their current sharpening characteristics and the second while skating on sharpening characteristics applied for the purpose of the study. Players were not informed with regards to what adjustments were made to their current skate blades and were, therefore, blinded to the characteristics they were skating on for the recommended sharpening condition. All players were informed of the study details and requirements in writing through the letter of invitation and informed consent, as well as verbally prior to the first on-ice assessment session. Players were required to provide informed consent. Players not of legal age to provide informed consent (ages 17 years or younger) required consent from their parent or legal guardian. Anthropometric measures consisting of height (cm) and weight (kg) were recorded for each player (Table 1). Sport specific demographics including current team/level of play, position, and years of experience, along with equipment information detailing players' skate preferences including skate brand/model, blade holder brand/model, and skate blade brand/model were also recorded (Tables 1-3). The study received ethical approval from the Brock University Research Ethics Board (File #: 14-303).

3.5 Skate Blade Measurements and Sharpening

The players' current sharpening characteristics were defined by measuring ROC, ROH, pitch and edge levelness for each player's right and left skate blade (Table 4). All measurements were taken by the same experienced skate sharpening technician to ensure consistency. Radius of contour (ROC) was determined using standardized ROC templates (Maximum Edge™, Windsor, ON). Radius of hollow (ROH) was measured using a Hollow Depth Indicator™ positioned at three designated blade locations; 25%, 50%, and 75% of blade length (Edge Specialties Inc., Alexandria, MN). Pitch was determined by measuring blade height (mm) at two designated blade locations; 25% and 75% of blade length. If the front and rear measurements were of equal heights, a neutral blade pitch was assumed. If the front measurement was lower than the rear measurement, a forward pitch was assumed, whereas, if the front measurement was higher than the rear measurement, a backwards pitch was assumed. A greater difference between the front and rear measurements indicated a larger magnitude of pitch. Measurements of edge levelness were taken at 25% and 75% of the blade length using a Quick Square™ to measure levelness (Maximum Edge™, Windsor, ON). Edges measured to less than 1/1000th in. discrepancy in height were considered to be level edges, whereas, edges measured to greater than 1/100th in. discrepancy in height were considered to be unleveled edges. If discrepancies existed between the measurements taken for a player's right and left skate blades, the longer ROC, deeper ROH, greater pitch and greater edge levelness values where used for all further comparisons.

The recommended sharpening characteristics for each player were determined using the selection process previously indicated and outlined in *Figure 6*. If a player's current sharpening characteristic matched the recommended sharpening characteristic defined by the parameters given, then the current sharpening characteristic was maintained for the recommended sharpening condition. Any characteristic that was maintained between conditions was reapplied prior to the second on-ice assessment in order to ensure a game ready sharpening as utilized in the first on-ice assessment. The recommended sharpening characteristics were applied using practices accepted within the skate sharpening industry. Radius of contour (ROC) and pitch were applied using a Blademaster custom radius contouring system with contour radius bars and a Blademaster CRM6 blade holder (Guspro, Inc., Chatham, ON). All shaping and sharpening of the blades was conducted by the same experienced skate sharpening technician using a Blademaster Legend, triple station system (Guspro, Inc., Chatham, ON). Edge levelness was verified after each sharpening to be within 1/1000th in. using a Quick Square^{TM} measuring device (Maximum Edge^{TM}, Windsor, ON).

3.6 On-Ice Assessment

Two on-ice assessment sessions were scheduled; the first session required players to complete a battery of eight skating drills while skating on their current sharpening characteristics, and the second session required players to repeat the drills while skating on the recommended sharpening characteristics. On-ice assessments were scheduled a minimum of seven days apart. Seven of the drills represented isolated skating skills typically used in game play and one combined skills (CS) drill represented overall skating performance. Protocol for the on-ice assessment sessions was held constant across the two conditions. Players were required to wear full hockey equipment including the use of a stick. Players were fitted with a radio frequency identification (RFID) tag that was used to identify players with their respective skating times. Each session began with a ten minute on-ice warm up that consisted of a five minute unguided skate where the players were free to skate as desired and a five minute guided skate consisting of a 75% of maximal effort forward sprint, cross overs, pivots, backwards skating, and a maximal effort forward sprint. Order of the skating drills performed was held constant across sessions: forwards (FW), backwards (BW), agility (AG), stops and starts to the left and to the right (SSL/SSR), crossovers to the left and to the right (COL/COR), and the CS skating drill (Appendix E). The first drill (FW) was repeated in order to assess the reliability of the recorded skating times and to familiarize players with the timing light set up and drill execution. Times recorded during the second FW drill were used for comparison between sharpening conditions.

Players initiated each drill by swiping their RFID tag in front of a sensor board; the RFID tag identified the player within the computer recording system and activated the timing light system. Players then positioned themselves appropriately on a designated start line for the required drill (Appendix E). A green light, set to randomly trigger between five and ten seconds after the player signed in with their RFID tag, was used to signal the start of the drill (when time stared recording). Upon this signal the players proceeded to complete the given drill as fast as possible. Verbal encouragement was provided to all players for all drills in order to inspire maximal effort. Time for each drill stopped recording when the player passed the last timing light of the drill. If a player did not successfully complete a trial (e.g. they fell, missed or hit a cone, or improperly completed the drill), the player was required to repeat the trial following adequate rest.

Interval and total times (s) were recorded for each drill using a Swift™ timing light system (Swift Performance Equipment, Carole Park, QLD). Placement, or spacing, of the timing lights was held constant for each drill between conditions. All timing lights were set up on a tripod to eliminate the chance of the player's hockey stick as opposed to their body breaking the laser and effecting skating times. Times recorded from the start of the drill when the green light was triggered to when the player passed the first timing light represented movement initiation time (T1; s). Times recorded from the start of the drill when the green light was triggered to when the player passed the last timing light represented total skating times (TT; s).

Upon completion of the second on-ice assessment session players were asked to complete a questionnaire that consisted of seven questions rating their perceptions of the recommended sharpening characteristics and their performance on a Likert scale from 1 to 5 and one question rating their effort throughout the trials based on a rate of perceived exertion (RPE) scale from 1-10 (Appendix D).

3.7 Data Analysis

All statistical analyses were completed using Statistical Package for the Social Sciences (SPSS) software, version 20.0 (IBM, Chicago, IL). Descriptive statistics including mean (M), standard deviation (SD) and frequencies were completed for all variables. Three one-way analysis of variances (ANOVAs) were conducted to determine if significant differences existed in player height (cm), weight (kg) and years of hockey experience across groups (U16, U18 and Minor Midget AAA). Three two-tailed independent samples t-tests were conducted to determine if significant difference existed in player height (cm), weight (kg) and years of hockey experience between positions (forwards and defense).

Pearson's product moment correlations were conducted for the T1's (s) and TT's (s) between the repeated FW drills for both on-ice assessments in order to assess the reliability of the skating drills; meaning were the times for the repeated drills correlated indicating a reliable test or not correlated indicating an unreliable test. Pearson's product moment correlations were considered to be appropriate calculations given the continuous nature of the T1 (s) and TT (s) data sets. Two-tailed paired samples t-tests were conducted on the T1's (s) from each of the eight skating drills across conditions to determine if significant differences existed between the current and the recommended sharpening conditions. Two-tailed paired samples t-tests were also conducted on the TT's (s) from each of the eight skating drills across conditions to determine if significant differences existed between the current and the recommended sharpening conditions.

Composite scores for T1 (s) and TT (s) were calculated as the sum of the T1's (s) or the TT's (s) respectively across the seven isolated skills drills. Analysis of the composite scores allowed for insight into a potential cumulative effect across the isolated skills drills and may be considered to better represent the potential effects as they relate to in game play when compared to the isolated skills drills. Two-tailed paired samples t-tests were conducted on the composite T1 (s) and TT (s) scores across conditions to determine if significant differences existed between the current and the recommended sharpening conditions. A Bonferroni correction was applied to correct for family wise error associate with conducting analyses on both movement initiation times (T1; s) and total skating times (TT; s).

For the purpose of further analysis, data was regrouped by the number of sharpening characteristics adjusted for each player; 1, 2, or 3. The number of sharpening characteristics adjusted varied based upon the player's current sharpening characteristics. For instance, if a player was currently skating on one of the recommended sharpening characteristics, then two of the three sharpening characteristics were adjusted between conditions, whereas, if the player was currently skating on two of the recommended sharpening characteristics, then only one of the three sharpening characteristics was adjusted between conditions. Multiple two-tailed paired samples t-tests were conducted on the T1's (s) and TT's (s) to determine if significant differences existed between the current and the recommended sharpening conditions for each group; 1 characteristic adjusted, 2 characteristics adjusted and 3 characteristics adjusted. Multiple two-tailed paired samples t-tests were also conducted on T1's (s) and TT's (s) for players who experienced adjustments to either 2 or all 3 characteristics in order to determine if significant differences existed between the current and the recommended sharpening condition for players who experienced an adjustment to the majority of their sharpening characteristics. Data was then regrouped by position of play, forwards or defense. Multiple two-tailed paired samples t-tests were conducted on the T1's (s) and TT's (s) to determine if significant differences existed between the current and the recommended sharpening conditions. Finally, data was regrouped by player weight, for players over 81.6 kg (180 lbs) and for players of 81.6 kg (180 lbs) or less. Multiple two-tailed paired samples t-tests were conducted on the T1's (s) and TT's (s) to determine if significant differences existed between the current and the recommended sharpening conditions. An alpha level of $p < 0.05$ was used for all statistical analyses.

Frequencies were calculated on questionnaire responses to identify player perceptions of the recommended sharpening characteristics in comparison to their current sharpening characteristics. Cumulative scores were calculated as the sum of the questionnaire responses across questions 1-5 that rated player perceptions of the performance of the recommended sharpening characteristics across isolated skating skills. In order determine if a reliable cumulative score could be calculated across questions 1-5, Cronbach's alpha was calculated to determine the internal consistency across these questions. Cronbach's alpha revealed an acceptable level of internal consistency (α = 0.74) across questions 1-5 and supported the potential to calculate a cumulative score across these questions. A Spearman's correlation coefficient was calculated to determine if a level of agreement existed between the cumulative scores across questions 1-5 and question 7 rating the player's overall skate sharpening preference.

Questionnaire responses for question 7 and the change in composite TT scores (s) between conditions were coded to allow for comparison between player preference and on-ice skating times. A questionnaire response of 4 or higher was considered to indicate that the player preferred the recommended sharpening condition and was given a value of 1. A questionnaire response of 3 or below was considered to indicate the player did not prefer the recommended sharpening condition and was given a value of 0. If the composite TT score decreased, indicating faster skating times while skating on the recommended sharpening condition then a value of 1 was given. If the composite TT score increased, indicating slower skating times while skating on the recommended sharpening condition a value of 0 was given. A Spearman's correlation coefficient was calculated on the coded data to determine if a level of agreement existed between player preference and faster skating times; in other words, did the players like what they skated fastest on? Spearman's correlations were selected as opposed to Pearson's correlations in order to correspond with the ordinal and nominal data associated with the questionnaire responses and coded data respectively.

Results

4.1 Descriptive Statistics

4.1.1 Player descriptives.

Descriptive statistics including mean, standard deviation and frequencies are illustrated in tables 1 and 2. Significant differences were revealed in player height (cm) and weight (kg) across groups (U16, U18, Minor Midget AAA). Players from the U16 group were significantly shorter and lighter (169.71 ± 6.88 cm; 66.38 ± 8.90 kg) when compared to players from both the U18 group (178.45 ± 8.03 cm; 76.14 ± 8.00 kg) and the Minor Midget AAA group (175.89 ± 4.99 cm; 75.89 ± 8.90 kg) ($p < .05$) (Table 1). No significant differences in height, weight or years of experience were observed between forwards and defense players.

4.1.2 Boot and blade descriptives.

Frequencies for skate boot brand, blade holder brand and skate blade brand are illustrated in table 3 to allow for a comparison of players' skates and skate blades as it pertains to the immediate parameters of the study. Seventy-three percent of the skate blades were determined to be factory stocked blades, 7% were aftermarket blades, and 20% of the blades were non identifiable. Frequencies for the ROC, ROH, pitch and edge levelness reflecting the players' current sharpening characteristics are illustrated in table 4. Five percent of the players were currently skating on the recommended double ROC of 2.74 m – 3.05 m (9 ft – 10 ft). Forty-three percent of players were currently skating on their recommended ROH. Thirty-five percent of players were skating on a forward pitch comparable to their recommended pitch setting. Sixty-eight percent of the players had at least one skate blade that had unleveled edges ranging between 1/1000th and 3/1000th of an inch, whereas 32% of players had level edges measuring within the accepted industry standard (Table 4). Measurements for the current sharpening characteristics were also used to determine the change in sharpening characteristics experienced by each player between conditions. It was revealed that 40% of players experienced an adjustment to all 3 sharpening characteristics, 43% of the players experienced an adjustment to 2 sharpening characteristics and 17% of the players experienced an adjustment to 1 sharpening characteristic (Table 5).

4.2 On-Ice Results

Skating times were normalized by body weight (kg) in order to facilitate a comparison of skating times across the three cohorts (U16, U18, Minor Midget AAA). A weak to moderate positive correlation was revealed for T1 (s/kg) ($r = 0.41$; $p = 0.008$) between the two FW drills for the first on-ice assessment. A significant positive correlation was revealed for TT (s/kg) ($r = 0.93$; $p < 0.001$) between the two FW drills for the first on-ice assessment. Significant positive correlations were also revealed for T1 (s/kg) and TT (s/kg) ($r = 0.88$; $p < 0.001$; $r = 0.99$; $p < 0.001$) between the two FW drills for the second on-ice assessment.

Tests for skewness and kurtosis revealed that T1's (s/kg) were normally distributed for the majority of the drills (Table 8 & 9). Skewness values greater than 1 were revealed in the first FW drill, the BW drill, and the AG drill for the first on-ice assessment, meaning that skating times for these drills had a high positive skew. Kurtosis values greater than 1 were revealed in the first FW drill, the BW drill, and the COL drill for the first on-ice assessment and in the second FW drill for the second on-ice assessment, meaning that skating times for these drills had a leptokurtic distribution. Kurtosis values less than negative 1 were revealed in the COR drill for the first on-ice assessment, meaning that skating times for this drill had a platykurtic distribution. Skewness and kurtosis values for all TT's (s/kg) were between 1 and negative 1 revealing a normal distribution for all skating times. Significant differences were revealed in T1 (s/kg) between conditions on 4 of the 8 skating drills; BW, SSL, SSR, and COR ($p < .05$) (Table 10). Significant differences were revealed in TT (s/kg) between conditions on 2 of the 8 skating drills; SSR and SSL ($p < .05$) (Table 11). Significant differences were revealed between conditions for the composite scores of both T1 (s/kg) and TT (s/kg) ($p < .05$) (Table 10 & 11). All significant differences revealed that faster skating times were achieved while skating on the recommended sharpening characteristics. Average reductions in skating times of 0.0011 s/kg and 0.0012 s/kg for T1 and TT respectively across the isolated skills drills and of 0.0052 s/kg and 0.0032 s/kg for the composite T1 and TT scores were revealed.

When player skating times were grouped by the number of sharpening characteristics adjusted (1, 2 or 3) limited significant differences were revealed in T1 (s/kg) and TT (s/kg) between conditions. No significant differences were revealed for T1 (s/kg) or TT (s/kg) between conditions for players who experienced an alteration to only one sharpening characteristic (Table 12 & 13). For players who experienced alterations to two sharpening characteristics, significant differences between conditions were revealed in T1 (s/kg) on 2 of the 8 skating drills; SSR and COR, in TT (s/kg) on 2 of the 8 skating drills; SSL and SSR and on the composite T1 (s/kg) and TT (s/kg) scores ($p < .05$) (Table 14 & Table 15). These significant differences revealed faster times for the recommended sharpening condition with an average reduction in T1 of 0.0015 s/kg and in TT of 0.0016 s/kg across the isolated skills drills and in the composite scores for T1 of 0.0062 s/kg and in TT of 0.0047 s/kg. For players who experienced alterations to all three sharpening characteristics, no significant differences were revealed in T1 (s/kg) or TT (s/kg) (Table 16 & 17). For players who experienced alterations to either two or three sharpening characteristics, significant differences between conditions were revealed in T1 (s/kg) on 3 of the 8 skating drills; BW, SSL, and COR, in TT (s/kg) on 2 of the 8 skating drills, SSL and SSR and on the composite T1 (s/kg) and TT (s/kg) scores ($p < .05$) (Table 18 & 19).

These significant differences revealed faster times for the recommended sharpening condition with an average reduction in T1 of 0.0012 s/kg and in TT of 0.0013 s/kg across the isolated skills drills and in the composite scores for T1 of 0.0053 s/kg and for TT of 0.0039 s/kg.

When player skating times were grouped by position (forward and defense), limited significant differences were revealed in T1 (s/kg) and TT (s/kg) between conditions. For forward players, significant differences between conditions were revealed in T1 (s/kg) on 2 of the 8 skating drills; BW and COR, and on the composite T1 (s/kg) score ($p < .05$) (Table 20). These significant differences revealed faster times for the recommended sharpening condition with an average reduction in T1 of 0.0014 s/kg across the isolated skills drills and in the composite score for T1 of 0.0057 s/kg. For defense players, significant differences between conditions were revealed in T1 (s/kg) on the COR skating drill, in TT (s/kg) on 2 of the 8 skating drills; SSL and SSR, and on the composite TT (s/kg) score ($p < .05$) (Table 22 & 23). These significant differences revealed faster times for the recommended sharpening condition with an average reduction in T1 of 0.0010 s/kg and in TT of 0.0021 s/kg across the isolated skills drills and in the composite score for TT of 0.0062 s/kg.

When player skating times were grouped by weight (≤81.6 kg; 180 lbs and >81.6 kg; 180 lbs) limited significant differences were revealed in T1 (s/kg) and TT (s/kg) between conditions. For players of 81.6 kg (180 lbs) or less, significant differences between conditions were revealed in T1 (s/kg) on 3 of the 8 skating drills; BW, SSR, and COR, in TT (s/kg) on 2 of the 8 skating drills; SSL and SSR and on the composite T1 (s/kg) score (Table 24 & 25). These significant differences revealed faster times for the recommended sharpening condition with an average reduction in T1 of 0.0016 s/kg and in TT of 0.0015 s/kg across the isolated skills drills and in the composite score for T1 of 0.0059 s/kg. For players over 81.6 kg (180 lbs), significant differences between conditions were revealed in TT (s/kg) on the COL skating drill ($p < .05$) (Table 27). This significant difference revealed faster times for the recommended sharpening condition with an average reduction in TT of 0.0012 s/kg.

4.3 Questionnaire Responses

Frequencies calculated for questionnaire responses are displayed in table 30. Cumulative scores, calculated as the sum of the ratings across questions 1-5 assessing player perceptions across isolated skating skills, revealed that in 64% of responses players had a positive perception of the recommended sharpening characteristics. In other words, they felt the recommended sharpening characteristics offered improved performance when compared to their current sharpening characteristics. Twenty-four percent of responses across questions 1-5 revealed a neutral perception of the recommended sharpening condition, meaning no preference was shown to either condition. Finally, a minority (12%) of responses indicated that players preferred their current sharpening characteristics. The Spearman's correlation coefficient calculated between the cumulative scores on questions 1-5 and question 7 responses revealed a moderate positive correlation ($\rho = 0.68$; $p < .001$). This indicates that the players' responses assessing the performance of the recommended sharpening characteristics on isolated skating skills were consistent with their response indicating overall sharpening preference. The Spearman's correlation coefficient calculated between the questionnaire responses indicating player preference for sharpening condition and the difference in skating times between conditions revealed a weak positive correlation ($\rho = 0.03$; $p = 0.85$). This signals that the players' preferred the sharpening characteristics were not necessarily the sharpening characteristics that they skated fastest on. Rate of perceived exertion scores (8.85 ± 1.09) revealed that players exerted a high amount of effort throughout the second on-ice session.

Discussion

Skating speed enhances the opportunity for a player to gain puck possession, attain desirable positioning and potentially developing a scoring opportunity. To date, researchers have investigated the effects of individual sharpening characteristics, radius of contour (ROC) and radius of hollow (ROH), on skating speed and specific skills such as stopping. However, as skate sharpening characteristics are suggested to interact, it is important to understand the combined effect of adjusting multiple characteristics simultaneously, on skating speed. The present study was the first that investigated the combined influence of skate blade sharpening characteristics, ROC, ROH, and pitch on player skating speed.

Skate sharpening characteristics are often applied within a specific range, for instance, single radius contours between 2.13 m - 3.05 m (7 ft - 10 ft) are typical for ice hockey players whereas contours outside this range are considered to be in the extreme ranges (Lockwood & Winchester, 2004). Given the limited range of characteristics that are conventionally applied within the industry, adjustments made to sharpening characteristics in attempts to promote improvements in performance, or faster skating times, are often minor changes. Descriptive statistics recorded for each player's current sharpening characteristics revealed that 60% of the players were currently skating on at least one of their recommended sharpening characteristics. Furthermore, the magnitude of change between the current and recommended sharpening conditions was minimal, for example, the majority of players were currently skating on a 2.74 m or 3.05 m (9 ft or 10 ft) single radius of contour and the recommended contour consisted of a 2.74 m – 3.05 m (9 ft – 10 ft) double contour. Comparable changes were also revealed between conditions for both ROH and pitch. Therefore, many players were, to a certain extent, already skating on characteristics similar to the recommended sharpening characteristics. This may be indicative of the players having gained some intuitive knowledge and education with respect to skate sharpening characteristics throughout their years of experience playing hockey. Due to the limited magnitude of change between conditions, the alterations made to each player's sharpening characteristics were not anticipated to create drastic decreases in skating times, but rather, were intended to provide the advantage of making already good skaters a fraction faster in attempt to provide the potential for in-game advantages. The differences in skating times between conditions supported these anticipated effects, with differences being on average 0.1 – 0.2 seconds.

Analysis of the movement initiation and total skating times (s/kg) revealed mixed results with regards to the significant differences that were observed between conditions, and therefore, were inconclusive with regards to supporting the hypotheses that the recommended sharpening condition would decrease T1 (s/kg) and TT (s/kg). The hypothesized effects were based upon the findings of previous researchers investigating the effects of isolated characteristics, ROC, ROH, and pitch (McKenzie, 2012; Winchester, 2007; Slawinski et al., 2010), whereas, the present study investigated alterations made to multiple characteristics simultaneously. Skate sharpening characteristics are suggested to interact with one another; therefore, the effects of adjusting multiple characteristics simultaneously, such as in the present study, may not be directly comparable to the effects of adjusting individual characteristics that have been presented in previous research. Furthermore, due to the complex relationship between skating skills and the blade-ice interaction, different sharpening characteristics are suggested to provide performance advantages for different skating skills. The recommended sharpening characteristics facilitated significantly faster skating times for drills representing select on-ice skating skills; namely, the BW, SSL, SSR and COR drills. Each of these drills requires a player to position their body weight over the front portion of the skate blade in order to effectively execute the required skill. Therefore, the results may be indicative of the recommended sharpening characteristics facilitating faster skating times for skating skills that require the player to be position in a more forward stance on the skate blade. Improvements in these on-ice skills are consistent with the adjustments made to blade pitch in the recommended sharpening condition. Specifically, a forward pitch, as applied to the skate blades of all players, is suggested to position the player in a more forward stance on the skate blade and facilitate skating skills associated with this body positioning, such as stops, starts, backwards skating, agility skating (such as cross overs), and movement initiation. The mixed results revealed are reflective of the complex relationship between sharpening characteristics and skating performance, and promote concept that different sharpening characteristics facilitate different on-ice skating skills.

A potential contributing factor to the mixed results revealed may have been the change in sharpening characteristics (ROC, ROH, and pitch) experienced by each player between conditions. For ROC, a combined contour such as that applied for the present study, was suggested to provide performance advantages that arise from the combination of a longer rear contour (3.05 m or 10 ft for the recommended ROC) allowing for faster skating speeds and a shorter front contour (2.74 m or 9 ft for the recommended ROC) that enables maneuverability. McKenzie (2012) provided support for the potential benefits of a combined contour by revealing faster linear skating times when a combined contour was used in place of a traditional single contour. However, with the application of a combined contour in the present study, significantly faster linear skating times were not achieved. This difference in results may be explained by the change in ROC length experienced by players in both studies. Specifically, in the study by McKenzie (2012) only 8% of players were currently skating on a ROC as long or longer than the experimental contour and no players were currently on a combined contour. Whereas, in the present study, 63% of players were skating on a ROC as long or longer than the recommended contour and 5% were already on the recommended combined contour. In other words, a smaller percentage of players in the present study experienced an increase in contour length between conditions when compared to the study by McKenzie (2012). Due to the suggested relationship between contour length and skating speed, longer contours allow for faster skating speeds, the change in contour length between conditions could have potentially been a contributing factor to the different results revealed between studies. Similarly, the change in contour between conditions in the present study may also have been a contributing factor to the mixed results. Some players experienced an increase in contour length whereas experienced no change or a decrease in contour length and thus, different players may have been experiencing opposing effects on skating speed from the recommended ROC. The differences revealed in TT's (s/kg) between conditions for players that experienced an isolated adjustment to ROC provides support for the concept that the recommended ROC may have had a variable influence on total skating times. When only ROC was adjusted, all players were changed from a current ROC of 3.05 m (10 ft) or greater to the recommended 2.74 m – 3.05 m (9 ft -10 ft) double contour, meaning they experienced no change or a reduction in contour length. Average TT's (s/kg) for these players revealed that 8 of the 9 TT's (s/kg) were higher, indicating slower skating speeds, for the recommended sharpening condition.

When considering the potential influence of ROH on skating speed, Federolf and Redmond (2010) suggested that only extremely deep hollows would significantly reduce skating times, whereas hollow depths such as those measured and applied in the present study produced no significant differences in skating speeds. This opposes the concept that ROH may have contributed to differences in linear skating times and, therefore, to the mixed results. However, ROH has also been shown to have the potential to effect stopping time and distance (Gagnon & Dore, 1983; Winchester, 2007) and, therefore, may have influenced times recorded during the drills consisting of stop and start maneuvers. The change in ROH between conditions for the present study varied by player; 43% of players experienced no change in ROH, 47% of players experienced a shallower hollow and 10% of players experienced a deeper hollow while skating on the recommended sharpening condition. Therefore, the variability in the change in ROH between conditions on an individual player basis may have led to different players experiencing different effects and thus contributed to the mixed significant differences revealed.

Due to the lack of research investigating the effects of pitch on skating speed, a theoretical effect of a forward blade pitch on movement initiation was extrapolated from research on sprint starts (Schot & Knutzen, 1992; Slawinski et al., 2010). Significant differences were revealed in T1 (s/kg) for half (4 out of 8) of the skating drills, potentially indicating that a forward blade pitch does not in fact influence on-ice movement initiation, or that the effects of a forward pitch when related to sprinting starts do not associate with the effects of a forward skate blade pitch. With limited empirical evidence supporting the ability of pitch to effect on-ice skating times, it is unclear as to whether pitch may have been a contributing factor to the mixed results. However, although not always statistically significant, faster T1 (s/kg) times were achieved across all skating drills while skating on the recommended sharpening condition. These findings may allude to the potential of a forward pitch, as applied for the recommended sharpening condition, to influence on-ice movement initiation similar to that observed in sprint starts.

Results obtained from the analysis of the group data were comparable to those from the combined group in that they also revealed decreases in skating times across select drills typically representing skating skills that require the player to be positioned in a more forward stance. However, analysis of the grouped data also allowed for further insight into potential contributing factors as to why significant differences were observed across these select drills and whether or not the recommended characteristics offered greater benefits to a specific cohort of players. When grouped by the number of characteristics adjusted, some players experienced an alteration to only one sharpening characteristic while others experienced alterations to two or all three. This was due to the fact that some players were currently skating on one or two of the recommended sharpening characteristics. The different results revealed for players who experienced changes to a different number of characteristics supported the potential for the number of sharpening characteristics adjusted to have contributed to the mixed results. Specifically, when only one or all three characteristic were adjusted no significant differences in skating times were revealed, whereas, when two characteristics were adjusted, significant differences were revealed in up to 6 out of the 18 analyzed skating times. These findings supported the additional hypothesis that stated players would experience a different influence, or change in skating times, from the recommended sharpening characteristics based upon the number of characteristics adjusted between conditions.

Different recommended sharpening characteristics were selected and applied for players based upon position in attempts to accommodate the positional demands of the game. Specifically, different pitch settings were selected for defense and forward players. Therefore, it could be speculated that the different pitch settings may have offered different performance advantages to the forwards and defense players. A forward pitch was selected for players of both positions in an attempt to enhance movement initiation and acceleration (Slawinski et al., 2010). The consistent decreases in T1 (s/kg) while skating on the recommended sharpening condition were consistent with the proposed effect of a forward pitch as suggested based upon the findings of Slawinski et al. (2010) and support the rational for the pitch selection made for both forwards and defense players. Furthermore, comparable significant differences were revealed in T1 (s/kg) for both forwards and defense players, indicating that players from both positions benefitted equally from their recommended sharpening characteristics in terms of movement initiation. The greater forward pitch applied to the skate blades of defense players was intended to offer additional performance advantages by potentially allowing players to produce greater impulse forces in the direction of travel that are characteristic of skills related to the positional demands of the game, such as starts, stops, and pivots (Behm, Wahl, Button, Power, & Anderson, 2005; Slawinski et al., 2010). Faster skating times achieved by the defense players only while executing the stop and start maneuver drills supports the recommended pitch selection made in order to enhance performance in these position dependent skills and reinforces the concept that the different pitch settings facilitated different performance advantages. These findings also supported the additional hypothesis that stated players would experience a different influence, or change in skating times, from the recommended sharpening characteristics based upon position.

Similar to the differences in pitch based upon position, different ROHs selected based upon player weight could be suggested to offer different performance advantages to the relatively lighter (≤81.6 kg; 180 lbs) and relatively heavier (>81.6 kg; 180 lbs) players respectively. The relatively lighter players achieved significantly faster skating times while skating on the recommended sharpening condition for 6 of the 18 analyzed skating times, whereas, the relatively heavier players achieved significantly faster times on only 1 of the 18 analyzed skating times. Therefore, it may be speculated that the recommended ROH provided performance advantages to the relatively lighter players and not the relatively heavier players. However, as previously discussed, Federolf and Redmond (2010) suggested that ROHs within the range applied for the present study would have no effect on skating speed and, again, opposes the concept that ROH was responsible for the differences in decreased skating times experienced by the relatively lighter and heavier players. Furthermore, the weight based selection of ROH was adopted based upon the advantages reported by Lockwood and Winchester (2004). These advantages were, however, with respect to anaerobic performance and a player's ability to maintain a higher skating speed as opposed to actually skating faster; meaning the players did not necessarily achieve a faster top speed but rather were able to skate at a given speed for longer. An alternative explanation for the differences observed between the two weight groups may be the group size for the relatively heavier players. Only 7 of the 40 overall players were considered to be relatively heavier, therefore, it is possible that the number of relatively heavier players was simply too small to reveal any significant differences within the data that were revealed for the relatively lighter players.

In order to fully understand the influence of the recommended sharpening characteristics and the changes in skating times on performance, it is important to consider them in the context of a game situation. To do so, the changes in skating times can be converted to distance travelled on the ice surface. The T1 (s/kg) times for the seven isolated skills drills were on average 6.6% faster when the players were skating on the recommended sharpening characteristics. This represents the player being an average of 0.03 m further ahead after the first 0.61 m of the drill. For the combined skills drill a 1.4% decrease in T1 (s/kg) was revealed for the recommended sharpening condition. This represents a difference of 0.08 m over the first 5.49 m of the drill. Despite 0.03 m and 0.08 m being relatively small values, they indicate the potential for a player to react faster and cover greater distances in game like situations. The TT's (s/kg) for the seven isolated skills drills were on average 0.68% faster when the players were skating on the recommended sharpening characteristics. This represents the player being on average 0.14 m further forward at the end of the drills ranging in length from 18.9 m to 28 m.

These values include the BW skating drill, the only drill to display an increase in skating time with the recommended sharpening characteristics. If the six isolated skills drills that displayed decreases in time are analyzed independently, these values increase to 0.75% and 0.19 m. For the combined skills drill there was only a 0.3% decrease in time with the recommended sharpening condition, however, over the course of the drill this represents 0.31 m or over a foot difference. Although 0.19 m and 0.31 m may seem like relatively small distances, in the context of a game situation this could mean a player is able to attain desirable positioning over an opponent, gain puck possession, or even develop a scoring opportunity. Therefore, although not always statistically significant, the consistent decreases in skating times associated with the recommended sharpening condition may have the potential to offer significant in game advantages.

Player perceptions of the performance elicited by the recommended sharpening characteristics for select on-ice skating skills were consistent with the player’s overall sharpening preference. Specifically, players indicated that they preferred the recommended sharpening characteristics when compared to their current sharpening characteristics and felt that the recommended sharpening characteristics offered the best performance. However, the players’ perceived improvements in all isolated skating skills as indicated by the questionnaire responses did not agree with the on-ice results for the isolated skills drills. In other words, the players did not necessarily prefer the sharpening characteristics that they skated the fastest on. When considering the relationship between player perceptions of improved performance and the difference in composite skating times between conditions, it may be suggested that the players were unable to identify improvements in skating performance between sharpening conditions. This may potentially be due to the limited magnitude of change in sharpening characteristics between conditions, making it more difficult for players to differentiate between the performances of the two conditions. Additionally, the differences in skating times between conditions averaged between 0.1 - 0.2 seconds; therefore, the player's perception simply may not have been sensitive enough to identify the differences between conditions.

Certain limitations associated with the study design had the potential to influence the study results. For instance, the study was limited to two on-ice assessment sessions and the order of the conditions was restricted to the current sharpening condition preceding the recommended sharpening condition. Due to these limitations, it could be suggested that a potential learning effect may be present within the results, meaning any decrease in skating times recorded may have been due to the players becoming familiar with executing the skating drills as opposed to the change in sharpening characteristics. In attempt to limit the potential influence of a learning effect, only players who were currently competing at a competitive level were recruited to participate. Players had an average of 10 (± 1.9) years of hockey playing experience; it was, therefore, reasonable to assume that all players had considerable experience performing the skating maneuvers associated with the on-ice assessments and were not learning new skills throughout the on-ice battery but rather were executing skills already acquired. Thus, player selection limited the potential for a learning effect between conditions associated with skill acquisition. The limited familiarization period also created the potential for a learning effect within the results as players may have still been becoming comfortable with the new sharpening characteristics applied for the recommended sharpening condition. In other words, players may have skated slower at the start of the session and increased speed throughout duration of the session as they became more comfortable with the recommended sharpening characteristics. However, the strong correlations in total skating times revealed between the repeated FW drills for the second on-ice assessment session indicates that players skated at similar speeds between trials and provides a basis to suggest that there was a no learning effect associated with the time to complete each drill. The consistency in times recorded for the repeated drills also indicates the reliability of the on-ice assessment utilized. There was, however, a weak-to-moderate correlation in movement initiation times between the repeated FW drills in the first on-ice assessment session, with faster times being recorded during the second trial. This may be representative of the players becoming familiar with the timing light system and the initiation of the drill during their first attempt; on their first attempt players were learning how to position themselves on the start line and where to look for the green light that signaled the initiation of the drill.

In conclusion, skating in the sport of ice hockey is characterized by a variety of on-ice skating skills and can be influenced through the blade shaping and sharpening process. Current research has provided a fundamental understanding of the effects of sharpening characteristics on skating speed and how individual characteristics may be selected based upon player weight. The present results are indicative of the complex interaction between skate blade sharpening characteristic and how combining different characteristics may provide performance advantages during specific on-ice skating skills or for different players. Moreover, the results promote the concept that no single skating sharpening is optimal for all players or all skating skills. Future research should further investigate the interaction between sharpening characteristics and how adjusting one characteristic may influence how another contributes to the blade-ice interaction and ultimately on-ice performance; for example, how does adjusting ROC influence the contribution of ROH to on-ice performance.

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Table 1

Player Demographics Average (SD)

Group	Age (years)	Height (cm)	Weight (kg)	Years of Experience
Combined (*n* = 40)	16(1.2)	172.5(8.26)	69.5(9.67)	10 (1.9)
Midget (*n* = 9)	15(0)	176.0 (4.99)*	76.0(8.90)*	10(1.1)
U16 (*n* = 21)	15(.75)	169.5(6.88)	66.5(8.90)	10(1.9)
U18 (*n* = 10)	17(.52)	178.5(8.03)*	76.0(8.00)*	11(1.7)

*Significantly greater than U16 ($p < .05$)

Table 2

Position Demographics Average (SD)

Position	Age (years)	Height (cm)	Weight (kg)	Years of Experience
Forwards (*n* = 26)	16(1.2)	172.5 (8.66)	69.5 (10.2)	10 (1.7)
Defense (*n* = 14)	16(1.1)	174.5 (5.62)	74.0 (8.39)	10 (1.9)

Table 3

Skate Descriptives

Skate Brand	Frequency (*n*)	Percentage (%)
Bauer	36	90
CCM	4	10
Blade holder Brand		
Tuuk	36	90
SB +4.0	4	10
Blade		
Tuuk (Stock blades)	26	65
CCM Hyperglide (Stock blades)	3	8
Step Steel (Aftermarket blades)	2	5
RZR (Aftermarket blades)	1	2
Non Identifiable	8	20

Table 4

Current Sharpening Characteristics

Characteristics	Frequency (*n*)	Percentage (%)
ROC		
8	1	2
9	12	30
10	16	40
11	7	18
12	1	2
other	3	8
ROH		
<1/2	16	40
1/2	20	50
5/8	0	0
>5/8	4	10
Pitch		
Neutral	22	55
1/32 in. Forward Pitch	10	25
2/32 in. Forward Pitch	4	10
1/32 in. Backward Pitch	4	10
Edge Levelness		
Yes	13	32
No	27	68

Table 5

Frequency of Players Grouped by the Number of Sharpening Characteristics Adjusted

Number of Sharpening Characteristics Adjusted	Frequency (*n*)	Percentage (%)
3	16	40
2	17	43
1	7	17

Table 6

Movement Initiation Times (T1; s/kg)

	ICE 1										ICE 2									
Player ID	FW1	FW2	BW	AG	SSL	SSR	COL	COR	CS	COMP	FW1	FW2	BW	AG	SSL	SSR	COL	COR	CS	COMP
1019	0.0110	0.0093	0.0136	0.0083	0.0098	0.0099	0.0103	0.0096	0.0278	0.0707	0.0090	0.0089	0.0160	0.0101	0.0133	0.0120	0.0106	0.0122	0.0278	0.0830
1023	0.0082	0.0079	0.0110	0.0054	0.0097	0.0095	0.0100	0.0093	0.0269	0.0627	0.0088	0.0102	0.0130	0.0118	0.0117	0.0103	0.0067	0.0115	0.0276	0.0753
1028	0.0095	0.0091	0.0113	0.0098	0.0108	0.0086	0.0089	0.0094	0.0248	0.0677	0.0056	0.0084	0.0111	0.0092	0.0076	0.0094	0.0090	0.0105	0.0243	0.0653
1057	0.0110	0.0066	0.0122	0.0076	0.0100	0.0099	0.0096	0.0088	0.0268	0.0647	0.0076	0.0082	0.0121	0.0077	0.0104	0.0101	0.0093	0.0105	0.0264	0.0683
1067	0.0092	0.0069	0.0120	0.0079	0.0093	0.0086	0.0120	0.0087	0.0245	0.0654	0.0072	0.0094	0.0119	0.0069	0.0107	0.0102	0.0084	0.0118	0.0258	0.0693
1085	0.0078	0.0065	0.0123	0.0086	0.0112	0.0104	0.0091	0.0099	0.0278	0.0680	0.0090	0.0090	0.0117	0.0097	0.0097	0.0091	0.0091	0.0103	0.0255	0.0685
1086	0.0137	0.0120	0.0142	0.0075	0.0126	0.0125	0.0112	0.0130	0.0320	0.0830	0.0100	0.0107	0.0143	0.0099	0.0123	0.0126	0.0082	0.0106	0.0313	0.0786
1088	0.0160	0.0062	0.0117	0.0141	0.0100	0.0080	0.0089	0.0095	0.0225	0.0684	0.0075	0.0078	0.0105	0.0074	0.0079	0.0095	0.0079	0.0099	0.0223	0.0609
1098	0.0305	0.0094	0.0150	0.0133	0.0144	0.0138	0.0115	0.0130	0.0331	0.0904	0.0091	0.0077	0.0145	0.0119	0.0103	0.0149	0.0117	0.0138	0.0314	0.0847
1008	0.0189	0.0114	0.0138	0.0125	0.0131	0.0112	0.0107	0.0131	0.0327	0.0857	0.0114	0.0114	0.0133	0.0118	0.0099	0.0063	0.0117	0.0068	0.0283	0.0712
1009	0.0073	0.0054	0.0136	0.0103	0.0113	0.0117	0.0089	0.0113	0.0264	0.0725	0.0074	0.0066	0.0132	0.0093	0.0092	0.0094	0.0095	0.0093	0.0222	0.0665
1018	0.0061	0.0102	0.0154	0.0082	0.0115	0.0093	0.0114	0.0106	0.0320	0.0766	0.0128	0.0121	0.0166	0.0118	0.0106	0.0102	0.0116	0.0087	0.0321	0.0816
1019	0.0070	0.0058	0.0155	0.0067	0.0099	0.0107	0.0175	0.0123	0.0134	0.0784	0.0104	0.0087	0.0124	0.0102	0.0104	0.0093	0.0099	0.0080	0.0272	0.0689
1025	0.0123	0.0132	0.0215	0.0115	0.0158	0.0116	0.0133	0.0142	0.0331	0.1010	0.0132	0.0128	0.0169	0.0141	0.0139	0.0142	0.0170	0.0083	0.0330	0.0973
1026	0.0126	0.0086	0.0137	0.0154	0.0120	0.0183	0.0120	0.0151	0.0383	0.0951	0.0121	0.0122	0.0133	0.0189	0.0110	0.0109	0.0119	0.0079	0.0294	0.0862
1027	0.0091	0.0089	0.0186	0.0125	0.0134	0.0117	0.0126	0.0148	0.0339	0.0926	0.0106	0.0107	0.0167	0.0106	0.0125	0.0114	0.0153	0.0123	0.0321	0.0894
1036	0.0175	0.0162	0.0174	0.0161	0.0127	0.0126	0.0142	0.0153	0.0413	0.1046	0.0144	0.0131	0.0153	0.0132	0.0125	0.0141	0.0150	0.0094	0.0370	0.0927
1044	0.0101	0.0068	0.0145	0.0095	0.0090	0.0121	0.0107	0.0123	0.0320	0.0748	0.0112	0.0094	0.0129	0.0104	0.0096	0.0093	0.0113	0.0090	0.0287	0.0719
1047	0.0182	0.0065	0.0119	0.0108	0.0079	0.0084	0.0106	0.0119	0.0277	0.0680	0.0085	0.0014	0.0129	0.0056	0.0089	0.0072	0.0088	0.0057	0.0280	0.0505
1051	0.0076	0.0062	0.0152	0.0126	0.0127	0.0141	0.0106	0.0145	0.0309	0.0859	0.0118	0.0114	0.0134	0.0148	0.0112	0.0114	0.0114	0.0104	0.0285	0.0840
1057	0.0068	0.0070	0.0160	0.0077	0.0075	0.0107	0.0087	0.0116	0.0292	0.0691	0.0091	0.0085	0.0141	0.0080	0.0090	0.0095	0.0091	0.0060	0.0230	0.0643
1063	0.0080	0.0060	0.0149	0.0077	0.0090	0.0097	0.0109	0.0115	0.0302	0.0696	0.0109	0.0103	0.0114	0.0126	0.0101	0.0098	0.0107	0.0090	0.0347	0.0739
1067	0.0090	0.0095	0.0143	0.0102	0.0093	0.0126	0.0096	0.0113	0.0184	0.0770	0.0094	0.0062	0.0131	0.0119	0.0107	0.0105	0.0100	0.0063	0.0283	0.0687

1074	0.0071	0.0066	0.0102	0.0076	0.0091	0.0075	0.0081	0.0083	0.0212	0.0573	0.0071	0.0081	0.0101	0.0105	0.0081	0.0085	0.0087	0.0072	0.0213	0.0612
1077	0.0083	0.0108	0.0139	0.0109	0.0139	0.0111	0.0119	0.0145	0.0352	0.0871	0.0118	0.0078	0.0154	0.0122	0.0120	0.0071	0.0133	0.0107	0.0322	0.0786
1079	0.0194	0.0085	0.0123	0.0091	0.0107	0.0098	0.0096	0.0116	0.0311	0.0715	0.0109	0.0098	0.0133	0.0101	0.0100	0.0097	0.0102	0.0073	0.0280	0.0705
2007	0.0148	0.0148	0.0186	0.0155	0.0153	0.0158	0.0124	0.0143	0.0329	0.1067	0.0131	0.0116	0.0148	0.0139	0.0111	0.0113	0.0095	0.0124	0.0320	0.0846
2009	0.0142	0.0154	0.0235	0.0227	0.0143	0.0140	0.0116	0.0128	0.0271	0.1143	0.0103	0.0111	0.0139	0.0131	0.0131	0.0115	0.0104	0.0115	0.0285	0.0847
2010	0.0191	0.0168	0.0201	0.0173	0.0148	0.0135	0.0117	0.0138	0.0369	0.1081	0.0135	0.0125	0.0186	0.0132	0.0136	0.0129	0.0119	0.0134	0.0366	0.0961
2011	0.0142	0.0139	0.0189	0.0141	0.0135	0.0146	0.0119	0.0136	0.0308	0.1006	0.0120	0.0120	0.0164	0.0127	0.0123	0.0104	0.0119	0.0107	0.0295	0.0864
2014	0.0108	0.0122	0.0151	0.0134	0.0093	0.0087	0.0048	0.0091	0.0243	0.0726	0.0107	0.0082	0.0111	0.0073	0.0103	0.0077	0.0053	0.0084	0.0237	0.0583
2017	0.0117	0.0118	0.0155	0.0124	0.0126	0.0125	0.0107	0.0116	0.0254	0.0870	0.0096	0.0090	0.0133	0.0091	0.0087	0.0092	0.0075	0.0099	0.0250	0.0669
5006	0.0121	0.0117	0.0158	0.0117	0.0112	0.0120	0.0095	0.0125	0.0289	0.0843	0.0119	0.0109	0.0155	0.0104	0.0121	0.0123	0.0089	0.0116	0.0295	0.0817
5011	0.0091	0.0074	0.0128	0.0107	0.0083	0.0083	0.0044	0.0082	0.0228	0.0600	0.0054	0.0047	0.0114	0.0087	0.0083	0.0092	0.0058	0.0070	0.0222	0.0550
5021	0.0109	0.0107	0.0133	0.0112	0.0120	0.0117	0.0103	0.0134	0.0310	0.0825	0.0118	0.0132	0.0157	0.0143	0.0130	0.0127	0.0127	0.0116	0.0281	0.0931
5022	0.0095	0.0094	0.0128	0.0086	0.0104	0.0105	0.0109	0.0099	0.0266	0.0725	0.0086	0.0082	0.0145	0.0086	0.0097	0.0099	0.0101	0.0100	0.0260	0.0709
6002	0.0081	0.0083	0.0131	0.0087	0.0093	0.0089	0.0066	0.0072	0.0221	0.0620	0.0076	0.0071	0.0124	0.0086	0.0082	0.0078	0.0060	0.0084	0.0222	0.0585
6005	0.0170	0.0164	0.0212	0.0178	0.0161	0.0129	0.0114	0.0145	0.0340	0.1103	0.0151	0.0126	0.0191	0.0175	0.0107	0.0134	0.0113	0.0142	0.0362	0.0989
6011	0.0101	0.0074	0.0133	0.0109	0.0105	0.0106	0.0097	0.0112	0.0261	0.0735	0.0098	0.0089	0.0124	0.0095	0.0105	0.0103	0.0083	0.0097	0.0274	0.0696
6013	0.0132	0.0115	0.0137	0.0129	0.0093	0.0096	0.0079	0.0091	0.0229	0.0739	0.0064	0.0080	0.0113	0.0050	0.0101	0.0071	0.0074	0.0087	0.0231	0.0576

Table 7

Total Skating Times (TT; s/kg)

	ICE 1										ICE 2									
Player ID	FW1	FW2	BW	AG	SSL	SSR	COL	COR	CS	COMP	FW1	FW2	BW	AG	SSL	SSR	COL	COR	CS	COMP
1019	0.0663	0.0651	0.0833	0.0707	0.0773	0.0748	0.0582	0.0575	0.2666	0.4869	0.0661	0.0663	0.0867	0.0722	0.0802	0.0768	0.0562	0.0592	0.2802	0.4977
1023	0.0671	0.0659	0.0826	0.0713	0.0751	0.0745	0.0588	0.0560	0.2632	0.4843	0.0675	0.0656	0.0852	0.0747	0.0789	0.0778	0.0580	0.0595	0.2694	0.4997
1028	0.0569	0.0563	0.0695	0.0594	0.0660	0.0641	0.0502	0.0483	0.2245	0.4137	0.0572	0.0572	0.0684	0.0602	0.0656	0.0655	0.0495	0.0495	0.2319	0.4158
1057	0.0651	0.0640	0.0809	0.0692	0.0732	0.0705	0.0553	0.0540	0.2577	0.4671	0.0646	0.0650	0.0798	0.0687	0.0741	0.0745	0.0533	0.0530	0.2538	0.4684
1067	0.0568	0.0563	0.0761	0.0636	0.0682	0.0654	0.0534	0.0485	0.2310	0.4314	0.0562	0.0566	0.0729	0.0620	0.0699	0.0689	0.0503	0.0512	0.2380	0.4318
1085	0.0644	0.0641	0.0735	0.0684	0.0767	0.0748	0.0534	0.0531	0.2654	0.4639	0.0654	0.0661	0.0748	0.0695	0.0739	0.0760	0.0520	0.0520	0.2621	0.4643
1086	0.0808	0.0789	0.0945	0.0814	0.0913	0.0907	0.0662	0.0666	0.3050	0.5696	0.0768	0.0775	0.0921	0.0819	0.0929	0.0896	0.0652	0.0660	0.3091	0.5653
1088	0.0616	0.0536	0.0666	0.0656	0.0634	0.0646	0.0470	0.0469	0.2216	0.4077	0.0538	0.0537	0.0646	0.0577	0.0641	0.0658	0.0466	0.0468	0.2187	0.3992
1098	0.0983	0.0769	0.0906	0.0815	0.0876	0.0881	0.0664	0.0667	0.3078	0.5577	0.0757	0.0741	0.0900	0.0826	0.0882	0.0904	0.0655	0.0617	0.3023	0.5525
1008	0.0860	0.0752	0.0994	0.0826	0.0859	0.0805	0.0622	0.0654	0.3122	0.5512	0.0752	0.0771	0.0996	0.0810	0.0822	0.0808	0.0671	0.0657	0.3150	0.5536
1009	0.0610	0.0605	0.0748	0.0654	0.0705	0.0703	0.0527	0.0541	0.2432	0.4484	0.0602	0.0592	0.0766	0.0658	0.0682	0.0673	0.0519	0.0541	0.2443	0.4431
1018	0.0767	0.0776	0.0927	0.0847	0.0840	0.0860	0.0668	0.0646	0.3092	0.5565	0.0777	0.0768	0.0956	0.0834	0.0852	0.0829	0.0667	0.0652	0.3180	0.5556
1019	0.0693	0.0685	0.0837	0.0742	0.0806	0.0745	0.0649	0.0597	0.2779	0.5061	0.0693	0.0683	0.0840	0.0750	0.0775	0.0753	0.0558	0.0581	0.2739	0.4940
1025	0.0887	0.0883	0.1122	0.0939	0.1029	0.1031	0.0769	0.0781	0.3498	0.6553	0.0868	0.0875	0.1105	0.0963	0.0989	0.1021	0.0792	0.0771	0.3573	0.6516
1026	0.0848	0.0872	0.0955	0.0917	0.0974	0.0987	0.0702	0.0719	0.3462	0.6127	0.0854	0.0842	0.0977	0.0957	0.0949	0.0903	0.0711	0.0705	0.3374	0.6042
1027	0.0814	0.0805	0.1081	0.0937	0.0940	0.0941	0.0746	0.0749	0.3454	0.6199	0.0820	0.0800	0.1210	0.0919	0.0929	0.0922	0.0751	0.0733	0.3412	0.6264
1036	0.1020	0.0989	0.1195	0.1031	0.1097	0.1112	0.0814	0.0771	0.3946	0.7008	0.0981	0.0985	0.1137	0.1026	0.1100	0.1089	0.0806	0.0818	0.3853	0.6960
1044	0.0763	0.0754	0.0920	0.0810	0.0862	0.0852	0.0663	0.0639	0.3028	0.5501	0.0758	0.0737	0.0934	0.0789	0.0832	0.0803	0.0631	0.0623	0.3135	0.5350
1047	0.0795	0.0704	0.0828	0.0771	0.0778	0.0804	0.0614	0.0627	0.2776	0.5127	0.0709	0.0694	0.0839	0.0735	0.0764	0.0786	0.0589	0.0629	0.2878	0.5036
1051	0.0696	0.0699	0.0839	0.0773	0.0828	0.0849	0.0591	0.0627	0.2823	0.5206	0.0699	0.0699	0.0868	0.0784	0.0783	0.0804	0.0592	0.0604	0.2860	0.5134
1057	0.0627	0.0608	0.0805	0.0688	0.0747	0.0745	0.0555	0.0576	0.2805	0.4724	0.0625	0.0619	0.0816	0.0670	0.0715	0.0710	0.0533	0.0565	0.2571	0.4627
1063	0.0697	0.0679	0.0855	0.0751	0.0801	0.0781	0.0602	0.0579	0.2810	0.5048	0.0691	0.0683	0.0805	0.0767	0.0758	0.0741	0.0614	0.0579	0.2809	0.4947
1067	0.0677	0.0683	0.0861	0.0724	0.0802	0.0800	0.0607	0.0589	0.2827	0.5064	0.0694	0.0691	0.0856	0.0762	0.0783	0.0758	0.0589	0.0588	0.2856	0.5028

1074	0.0539	0.0560	0.0664	0.0585	0.0617	0.0609	0.0479	0.0462	0.2194	0.3976	0.0538	0.0532	0.0661	0.0612	0.0623	0.0608	0.0468	0.0472	0.2260	0.3976
1077	0.0899	0.0889	0.1075	0.0934	0.0997	0.0999	0.0750	0.0746	0.3540	0.6391	0.0896	0.0900	0.1121	0.0941	0.0975	0.0965	0.0763	0.0751	0.3656	0.6415
1079	0.0858	0.0743	0.0924	0.0805	0.0861	0.0841	0.0624	0.0639	0.3096	0.5437	0.0746	0.0746	0.0940	0.0777	0.0815	0.0803	0.0623	0.0624	0.2960	0.5328
2007	0.0813	0.0848	0.0981	0.0839	0.0951	0.0990	0.0686	0.0669	0.3370	0.5965	0.0851	0.0842	0.1006	0.0880	0.0906	0.0909	0.0690	0.0678	0.3334	0.5911
2009	0.0681	0.0706	0.0922	0.0841	0.0819	0.0791	0.0590	0.0588	0.2778	0.5257	0.0690	0.0681	0.0856	0.0731	0.0772	0.0764	0.0583	0.0585	0.2728	0.4972
2010	0.0972	0.0951	0.1161	0.1029	0.1051	0.1033	0.0806	0.0813	0.3913	0.6844	0.0957	0.0948	0.1195	0.1003	0.1053	0.1018	0.0810	0.0814	0.3830	0.6841
2011	0.0731	0.0726	0.0936	0.0774	0.0866	0.0852	0.0594	0.0623	0.3006	0.5373	0.0743	0.0734	0.0931	0.0776	0.0828	0.0833	0.0625	0.0623	0.2997	0.5351
2014	0.0597	0.0605	0.0754	0.0643	0.0673	0.0652	0.0472	0.0518	0.2397	0.4317	0.0645	0.0614	0.0750	0.0667	0.0695	0.0686	0.0500	0.0502	0.2378	0.4414
2017	0.0616	0.0618	0.0763	0.0663	0.0727	0.0725	0.0538	0.0538	0.2610	0.4574	0.0643	0.0629	0.0770	0.0680	0.0698	0.0699	0.0543	0.0510	0.2616	0.4529
5006	0.0744	0.0741	0.0940	0.0790	0.0817	0.0836	0.0634	0.0661	0.3081	0.5419	0.0772	0.0745	0.0942	0.0789	0.0849	0.0831	0.0663	0.0652	0.3132	0.5470
5011	0.0615	0.0601	0.0726	0.0682	0.0687	0.0723	0.0516	0.0517	0.2582	0.4453	0.0605	0.0595	0.0724	0.0653	0.0684	0.0697	0.0516	0.0498	0.2460	0.4367
5021	0.0713	0.0719	0.0875	0.0858	0.0797	0.0806	0.0670	0.0631	0.3054	0.5356	0.0735	0.0748	0.0926	0.0841	0.0829	0.0825	0.0648	0.0633	0.2916	0.5449
5022	0.0681	0.0685	0.0889	0.0729	0.0792	0.0775	0.0610	0.0597	0.2802	0.5077	0.0688	0.0687	0.0933	0.0735	0.0750	0.0763	0.0593	0.0607	0.2810	0.5068
6002	0.0571	0.0573	0.0770	0.0642	0.0639	0.0642	0.0509	0.0497	0.2392	0.4271	0.0583	0.0573	0.0758	0.0645	0.0650	0.0646	0.0492	0.0484	0.2401	0.4249
6005	0.0887	0.0874	0.1141	0.0959	0.1042	0.0997	0.0770	0.0804	0.3642	0.6587	0.0882	0.0859	0.1139	0.0978	0.0982	0.1026	0.0772	0.0802	0.3574	0.6558
6011	0.0635	0.0624	0.0780	0.0734	0.0723	0.0722	0.0605	0.0587	0.2603	0.4775	0.0645	0.0626	0.0772	0.0695	0.0720	0.0706	0.0548	0.0557	0.2589	0.4623
6013	0.0581	0.0567	0.0679	0.0637	0.0650	0.0639	0.0512	0.0508	0.2391	0.4191	0.0570	0.0559	0.0683	0.0625	0.0633	0.0635	0.0498	0.0507	0.2347	0.4140

Table 8

Skewness and Kurtosis Values forT1 (s/kg)

		FW1	FW2	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current Characteristics	Skewness	1.6757	0.7066	1.1056	1.0128	0.4253	0.8004	-0.0430	-0.1196	-0.2593	0.6858
	Kurtosis	4.1572	-0.4625	0.8745	1.4841	-0.7453	0.9026	2.5023	-1.0750	0.6088	-0.4936
Recommended Characteristics	Skewness	-0.0024	-0.8187	0.5797	0.5054	0.1302	0.2831	0.5238	0.0538	0.3243	0.1636
	Kurtosis	-0.5292	1.6831	-0.0827	0.6640	-0.6958	-0.1814	0.7350	-0.5253	-0.4264	-0.7697

Table 9

Skewness and Kurtosis Values for TT (s/kg)

		FW1	FW2	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current Characteristics	Skewness	0.6274	0.6226	0.5748	0.5357	0.4980	0.5329	0.4563	0.4706	0.5613	0.5375
	Kurtosis	-0.4674	-0.2552	-0.2198	-0.3815	-0.4103	-0.4333	-0.4209	-0.4275	-0.1880	-0.3734
Recommended Characteristics	Skewness	0.5384	0.5807	0.5486	0.5398	0.6313	0.6997	0.5666	0.6193	0.5171	0.5734
	Kurtosis	-0.1926	-0.1175	-0.2918	-0.4705	-0.1479	-0.0605	-0.5709	-0.2228	-0.4649	-0.3664

Table 10

Combined Group T1 (s/kg)

	T1	FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0119	0.0097	0.0148	0.0112	0.0113	0.0112	0.0104	0.0117	0.0286	0.0804
Characteristics	SD	0.0048	0.0032	0.0031	0.0035	0.0023	0.0023	0.0023	0.0022	0.0055	0.0152
Recommended	AVG	0.0101	0.0095	0.0137*	0.0108	0.0106*	0.0103*	0.0101	0.0098*	0.0282	0.0748*
Characteristics	SD	0.0024	0.0024	0.0021	0.0029	0.0017	0.0020	0.0025	0.0021	0.0041	0.0124
T-test		0.0196	0.5456	0.0033	0.4422	0.0228	0.0143	0.2985	0.0001	0.4360	0.0004
Effect Size		0.5147	0.0925	0.4188	0.1309	0.3601	0.4047	0.1348	0.8678	0.0963	0.4040

* Recommended was significantly faster than current ($p < .05$).

Table 11

Combined Group TT (s/kg)

	TT	FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0726	0.0708	0.0878	0.0772	0.0814	0.0808	0.0614	0.0612	0.2893	0.5207
Characteristics	SD	0.0126	0.0115	0.0139	0.0116	0.0125	0.0128	0.0092	0.0094	0.0451	0.0794
Recommended	AVG	0.0714	0.0707	0.0884	0.0769	0.0802*	0.0797*	0.0608	0.0608	0.2887	0.5174*
Characteristics	SD	0.0112	0.0113	0.0148	0.0118	0.0119	0.0118	0.0098	0.0096	0.0442	0.0796
T-test		0.1023	0.5071	0.2606	0.5355	0.0046	0.0204	0.0953	0.2137	0.6116	0.0152
Effect Size		0.1085	0.0123	-0.0413	0.0254	0.1025	0.0926	0.0678	0.0366	0.0143	0.0405

* Recommended was significantly faster than current ($p < .05$).

Table 12

Movement Initiation Times (T1; s/kg) for Players with 1 Characteristic Adjusted

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0130	0.0098	0.0144	0.0105	0.0108	0.0118	0.0107	0.0118	0.0267	0.0798
Characteristics	SD	0.0042	0.0029	0.0032	0.0031	0.0021	0.0029	0.0011	0.0022	0.0047	0.0161
Recommended	AVG	0.0104	0.0097	0.0137	0.0120	0.0113	0.0102	0.0106	0.0092	0.0306	0.0766
Characteristics	SD	0.0023	0.0029	0.0015	0.0026	0.0012	0.0019	0.0023	0.0025	0.0067	0.0111
T-test		0.1624	0.9460	0.4021	0.1907	0.5862	0.1647	0.8044	0.0845	0.2988	0.4232
Effect Size		0.7847	0.0184	0.2900	-0.5228	-0.2720	0.6753	0.0873	1.1254	-0.6815	0.2372

Table 13

Total Skating Times (TT; s/kg) for Players with 1 Characteristic Adjusted

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0752	0.0722	0.0910	0.0778	0.0833	0.0822	0.0624	0.0623	0.2945	0.5311
Characteristics	SD	0.0094	0.0083	0.0114	0.0085	0.0106	0.0108	0.0076	0.0075	0.0376	0.0632
Recommended	AVG	0.0752	0.0722	0.0910	0.0778	0.0833	0.0822	0.0624	0.0623	0.2945	0.5311
Characteristics	SD	0.0094	0.0083	0.0114	0.0085	0.0106	0.0108	0.0076	0.0075	0.0376	0.0632
T-test		0.3556	0.1341	0.8343	0.2032	0.3532	0.4201	0.7052	0.8301	0.1670	0.9364
Effect Size		0.2366	-0.0722	0.0243	-0.1761	0.1267	0.1406	-0.0518	0.0239	-0.0697	0.0041

Table 14

Movement Initiation Times (T1; s/kg) for Players with 2 Characteristics Adjusted

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0108	0.0095	0.0151	0.0111	0.0116	0.0112	0.0109	0.0119	0.0283	0.0812
Characteristics	SD	0.0041	0.0034	0.0032	0.0040	0.0019	0.0019	0.0022	0.0020	0.0058	0.0145
Recommended	AVG	0.0101	0.0097	0.0138	0.0104	0.0108	0.0101*	0.0102	0.0100*	0.0281	0.0751*
Characteristics	SD	0.0021	0.0016	0.0022	0.0023	0.0016	0.0017	0.0021	0.0018	0.0040	0.0103
T-test		0.5264	0.7816	0.0523	0.4864	0.0311	0.0111	0.2525	0.0012	0.8064	0.0136
Effect Size		0.2097	-0.0788	0.4726	0.2079	0.4346	0.6462	0.3242	0.9602	0.0491	0.4986

* Recommended was significantly faster than current ($p < .05$).

Table 15

Total Skating Times (TT; s/kg) for Players with 2 Characteristics Adjusted

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0721	0.0711	0.0878	0.0775	0.0817	0.0808	0.0618	0.0614	0.2895	0.5221
Characteristics	SD	0.0123	0.0113	0.0143	0.0123	0.0119	0.0122	0.0093	0.0098	0.0461	0.0799
Recommended	AVG	0.0714	0.0707	0.0891	0.0766	0.0802*	0.0791*	0.0608	0.0608	0.2905	0.5174*
Characteristics	SD	0.0116	0.0115	0.0165	0.0115	0.0121	0.0114	0.0100	0.0096	0.0457	0.0814
T-test		0.4181	0.2078	0.2058	0.2343	0.0250	0.0074	0.1446	0.0970	0.5742	0.0376
Effect Size		0.0530	0.0353	-0.0831	0.0773	0.1222	0.1394	0.0982	0.0595	-0.0215	0.0579

* Recommended was significantly faster than current ($p < .05$).

Table 16

Movement Initiation Times (T1; s/kg) for Players with 3 Characteristics Adjusted

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0123	0.0097	0.0146	0.0114	0.0111	0.0111	0.0099	0.0114	0.0291	0.0792
Characteristics	SD	0.0057	0.0030	0.0027	0.0029	0.0025	0.0029	0.0028	0.0026	0.0056	0.0154
Recommended	AVG	0.0099	0.0095	0.0135	0.0110	0.0104	0.0108	0.0100	0.0097	0.0278	0.0749
Characteristics	SD	0.0026	0.0025	0.0020	0.0032	0.0020	0.0022	0.0032	0.0021	0.0048	0.0140
T-test		0.1061	0.7142	0.0500	0.6337	0.2431	0.6607	0.6412	0.0310	0.1009	0.0636
Effect Size		0.5949	0.0853	0.4878	0.1269	0.2886	0.1127	-0.0600	0.7587	0.2596	0.2912

Table 17

Total Skating Times (TT; s/kg) for Players with 3 Characteristics Adjusted

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0721	0.0700	0.0863	0.0764	0.0803	0.0805	0.0608	0.0602	0.2870	0.5146
Characteristics	SD	0.0145	0.0135	0.0146	0.0124	0.0144	0.0151	0.0103	0.0098	0.0497	0.0887
Recommended	AVG	0.0706	0.0700	0.0863	0.0764	0.0795	0.0793	0.0601	0.0598	0.2837	0.5114
Characteristics	SD	0.0126	0.0128	0.0145	0.0137	0.0136	0.0136	0.0107	0.0104	0.0484	0.0881
T-test		0.3638	0.9473	0.9941	0.9901	0.2402	0.1748	0.2072	0.4481	0.1667	0.1186
Effect Size		0.1094	0.0018	0.0004	-0.0008	0.0575	0.0877	0.0634	0.0422	0.0671	0.0359

Table 18

Movement Initiation Times (T1; s/kg) for Players with 2 or 3 Characteristics Adjusted

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0115	0.0096	0.0149	0.0112	0.0113	0.0112	0.0104	0.0116	0.0287	0.0802
Characteristics	SD	0.0049	0.0032	0.0029	0.0035	0.0022	0.0024	0.0025	0.0023	0.0056	0.0147
Recommended	AVG	0.0100	0.0096	0.0136*	0.0107	0.0106*	0.0104	0.0101	0.0099*	0.0279	0.0750*
Characteristics	SD	0.0023	0.0021	0.0021	0.0028	0.0018	0.0020	0.0026	0.0019	0.0043	0.0120
T-test		0.0870	0.9804	0.0049	0.3895	0.0258	0.0575	0.4506	0.0002	0.2198	0.0017
Effect Size		0.4231	0.0044	0.4843	0.1691	0.3554	0.3403	0.1056	0.8574	0.1561	0.3929

* Recommended was significantly faster than current ($p < .05$).

Table 19

Total Skating Times for Players (TT; s/kg) with 2 or 3 Characteristics Adjusted

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0721	0.0706	0.0871	0.0770	0.0810	0.0806	0.0613	0.0608	0.2883	0.5184
Characteristics	SD	0.0132	0.0122	0.0143	0.0121	0.0130	0.0135	0.0097	0.0096	0.0471	0.0831
Recommended	AVG	0.0710	0.0704	0.0877	0.0765	0.0799*	0.0792*	0.0605	0.0603	0.2872	0.5145*
Characteristics	SD	0.0119	0.0120	0.0154	0.0124	0.0126	0.0123	0.0102	0.0098	0.0464	0.0834
T-Test		0.2284	0.3558	0.2972	0.3890	0.0136	0.0067	0.0489	0.1132	0.4545	0.0080
Effect Size		0.0832	0.0181	-0.0444	0.0381	0.0894	0.1131	0.0817	0.0517	0.0233	0.0474

* Recommended was significantly faster than current ($p < .05$).

Table 20

Movement Initiation Times (T1; s/kg) for Forward Players

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0120	0.0105	0.0155	0.0113	0.0118	0.0113	0.0109	0.0117	0.0287	0.0829
Characteristics	SD	0.0053	0.0034	0.0034	0.0040	0.0023	0.0019	0.0024	0.0023	0.0061	0.0161
Recommended	AVG	0.0104	0.0098	0.0143*	0.0110	0.0110	0.0106	0.0104	0.0102*	0.0288	0.0773*
Characteristics	SD	0.0022	0.0020	0.0022	0.0023	0.0016	0.0022	0.0028	0.0021	0.0043	0.0118
T-test		0.1115	0.1266	0.0234	0.6477	0.0666	0.0896	0.3409	0.0057	0.8811	0.0055
Effect Size		0.4287	0.2739	0.4160	0.0942	0.3844	0.3438	0.1647	0.7101	-0.0224	0.4058

* Recommended was significantly faster than current ($p < .05$).

Table 21

Total Skating Times (TT; s/kg) for Forward Players

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0744	0.0728	0.0915	0.0788	0.0835	0.0823	0.0631	0.0627	0.2956	0.5346
Characteristics	SD	0.0137	0.0118	0.0143	0.0126	0.0132	0.0135	0.0098	0.0101	0.0482	0.0843
Recommended	AVG	0.0733	0.0725	0.0920	0.0788	0.0826	0.0818	0.0626	0.0626	0.2971	0.5330
Characteristics	SD	0.0116	0.0118	0.0152	0.0120	0.0125	0.0128	0.0104	0.0103	0.0466	0.0838
T-test		0.2658	0.2645	0.4479	0.9244	0.1128	0.3640	0.3936	0.7004	0.2207	0.3375
Effect Size		0.0917	0.0241	-0.0378	-0.0043	0.0692	0.0358	0.0447	0.0145	-0.0330	0.0194

Table 22

Movement Initiation Times (T1; s/kg) for Defense Players

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0117	0.0083	0.0136	0.0112	0.0105	0.0110	0.0096	0.0115	0.0284	0.0757
Characteristics	SD	0.0041	0.0025	0.0020	0.0026	0.0021	0.0030	0.0020	0.0022	0.0045	0.0126
Recommended	AVG	0.0094	0.0089	0.0127	0.0106	0.0099	0.0098	0.0094	0.0090*	0.0269	0.0703
Characteristics	SD	0.0025	0.0031	0.0015	0.0039	0.0015	0.0015	0.0018	0.0020	0.0037	0.0127
T-test		0.0857	0.4728	0.0576	0.5340	0.1993	0.0887	0.7020	0.0033	0.0989	0.0359
Effect Size		0.6972	-0.2238	0.5429	0.2019	0.3497	0.5281	0.0734	1.1895	0.3766	0.4295

* Recommended was significantly faster than current (p < .05).

Table 23

Total Skating Times (TT; s/kg) for Defense Players

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0693	0.0672	0.0810	0.0742	0.0776	0.0780	0.0584	0.0583	0.2778	0.4947
Characteristics	SD	0.0099	0.0102	0.0102	0.0092	0.0105	0.0112	0.0072	0.0074	0.0376	0.0641
Recommended	AVG	0.0678	0.0673	0.0817	0.0733	0.0757*	0.0756*	0.0574	0.0576	0.2730	0.4885*
Characteristics	SD	0.0097	0.0097	0.0115	0.0109	0.0094	0.0087	0.0076	0.0073	0.0357	0.0641
T-test		0.2143	0.7357	0.3333	0.3026	0.0085	0.0190	0.0557	0.0512	0.0716	0.0028
Effect Size		0.1563	-0.0131	-0.0598	0.0941	0.1930	0.2391	0.1342	0.0974	0.1291	0.0963

* Recommended was significantly faster than current (p < .05).

Table 24

Movement Initiation Times (T1; s/kg) for Players ≤180 lbs

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0123	0.0101	0.0154	0.0115	0.0117	0.0118	0.0109	0.0123	0.0298	0.0837
Characteristics	SD	0.0051	0.0034	0.0030	0.0037	0.0023	0.0021	0.0020	0.0019	0.0053	0.0146
Recommended	AVG	0.0108	0.0099	0.0143*	0.0114	0.0110	0.0106*	0.0106	0.0099*	0.0292	0.0777*
Characteristics	SD	0.0019	0.0024	0.0020	0.0028	0.0014	0.0021	0.0024	0.0022	0.0037	0.0116
T-test		0.1037	0.6250	0.0103	0.9284	0.0490	0.0063	0.4180	0.0000	0.4205	0.0011
Effect Size		0.4211	0.0840	0.4572	0.0160	0.3759	0.5422	0.1321	1.1729	0.1297	0.4548

* Recommended was significantly faster than current (*p* < .05).

Table 25

Total Skating Times (TT; s/kg) for Players ≤180 lbs

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0758	0.0738	0.0914	0.0801	0.0849	0.0841	0.0638	0.0638	0.3012	0.5420
Characteristics	SD	0.0116	0.0103	0.0124	0.0105	0.0109	0.0114	0.0083	0.0082	0.0401	0.0704
Recommended	AVG	0.0745	0.0738	0.0923	0.0800	0.0833*	0.0827*	0.0633	0.0633	0.3004	0.5387
Characteristics	SD	0.0097	0.0099	0.0130	0.0105	0.0106	0.0107	0.0089	0.0086	0.0395	0.0708
T-test		0.1680	0.7284	0.1269	0.9032	0.0025	0.0091	0.2492	0.1426	0.5521	0.0391
Effect Size		0.1205	0.0082	-0.0742	0.0059	0.1455	0.1340	0.0611	0.0552	0.0213	0.0459

* Recommended was significantly faster than current (*p* < .05).

Table 26

Movement Initiation Times (T1; s/kg) for Players >180 lbs

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0103	0.0080	0.0121	0.0102	0.0094	0.0085	0.0081	0.0086	0.0230	0.0650
Characteristics	SD	0.0032	0.0018	0.0012	0.0025	0.0008	0.0006	0.0023	0.0008	0.0013	0.0057
Recommended	AVG	0.0067	0.0076	0.0113	0.0081	0.0087	0.0088	0.0076	0.0091	0.0230	0.0611
Characteristics	SD	0.0009	0.0015	0.0008	0.0018	0.0012	0.0011	0.0013	0.0018	0.0015	0.0048
T-test		0.0224	0.6997	0.0402	0.1850	0.2651	0.6028	0.4462	0.4841	0.7135	0.1937
Effect Size		1.7983	0.2122	0.8671	1.0113	0.7489	-0.3634	0.2673	-0.3314	-0.0660	0.7349

Table 27

Total Skating Times (TT; s/kg) for Players >180 lbs

		FW	FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
Current	AVG	0.0580	0.0566	0.0709	0.0633	0.0653	0.0650	0.0503	0.0489	0.2333	0.4203
Characteristics	SD	0.0027	0.0019	0.0044	0.0034	0.0025	0.0035	0.0022	0.0020	0.0135	0.0159
Recommended	AVG	0.0567	0.0562	0.0698	0.0619	0.0655	0.0655	0.0491*	0.0491	0.2336	0.4171
Characteristics	SD	0.0024	0.0022	0.0040	0.0026	0.0027	0.0030	0.0018	0.0017	0.0091	0.0151
T-test		0.2809	0.3942	0.0577	0.3173	0.5602	0.5129	0.0200	0.7434	0.9062	0.1045
Effect Size		0.5161	0.1965	0.2563	0.4701	-0.1017	-0.1512	0.5905	-0.1100	-0.0301	0.2015

* Recommended was significantly faster than current ($p < .05$).

Table 28

Average (SD) T1's and the differences between conditions for each drill

Number of characteristics adjusted		FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
1	Current	0.0098 (0.0029)	0.0144 (0.0032)	0.0105 (0.0031)	0.0108 (0.0021)	0.0118 (0.0029)	0.0107 (0.0011)	0.0118 (0.0022)	0.0267 (0.0047)	0.0798 (0.0161)
	Recommended	0.0097 (0.0029)	0.0137 (0.0015)	0.012 (0.0026)	0.0113 (0.0012)	0.0102 (0.0019)	0.0106 (0.0023)	0.0092 (0.0025)	0.0306 (0.0067)	0.0766 (0.0111)
	Difference	5.32E-05	0.0007	-0.0015	-0.0005	0.0016	0.0002	0.0027	-0.0039	0.0032
2	Current	0.009522 (0.0034)	0.015072 (0.0032)	0.011085 (0.0040)	0.011574 (0.0019)	0.011244 (0.0019)	0.01087 (0.0022)	0.011864 (0.0020)	0.02833 (0.0058)	0.081231 (0.0145)
	Recommended	0.0097 (0.0016)	0.0138* (0.0022)	0.0104 (0.0023)	0.0108* (0.0016)	0.0101* (0.0017)	0.0102 (0.0021)	0.0100* (0.0018)	0.0281 (0.0040)	0.0751* (0.0103)
	Difference	-0.0002	0.0013	0.0007	0.0008	0.0012	0.0007	0.0018	0.0002	0.0062
3	Current	0.0097 (0.0030)	0.0146 (0.0027)	0.0114 (0.0029)	0.0111 (0.0025)	0.0111 (0.0029)	0.0099 (0.0028)	0.0114 (0.0026)	0.0291 (0.0056)	0.0792 (0.0154)
	Recommended	0.0094 (0.0025)	0.0134* (0.0020)	0.0110 (0.0032)	0.0104 (0.0020)	0.0108 (0.0022)	0.0100 (0.0032)	0.0097* (0.0021)	0.0278 (0.0048)	0.0749 (0.0140)
	Difference	0.0002	0.0011	0.0004	0.0006	0.0003	-0.0002	0.0018	0.0013	0.0043
2 or 3	Current	0.0096 (0.0032)	0.0149 (0.0029)	0.0112 (0.0035)	0.0113 (0.0022)	0.0112 (0.0024)	0.0104 (0.0025)	0.0116 (0.0023)	0.0287 (0.0056)	0.0802 (0.0147)
	Recommended	0.0096 (0.0021)	0.0136* (0.0021)	0.0107 (0.0028)	0.0106* (0.0018)	0.0104* (0.0020)	0.0101 (0.0026)	0.0099* (0.0019)	0.0279 (0.0043)	0.0750* (0.0120)
	Difference	1.16E-05	0.001213	0.000529	0.000698	0.00074	0.000273	0.001794	0.000778	0.005257

Note. Negative values (-) in the difference rows indicates that the time for the recommended condition were slower than the current condition.
* Recommended was significantly faster than current ($p < .05$).

Table 29

Average (SD) TT's and the differences between conditions for each drill

Number of characteristics adjusted		FW	BW	AG	SSL	SSR	COL	COR	CS	COMP
1	Current	0.0722 (0.0083)	0.0910 (0.0114)	0.0778 (0.0085)	0.0833 (0.0106)	0.0822 (0.0108)	0.0624 (0.0076)	0.0623 (0.0075)	0.2945 (0.0376)	0.5311 (0.0632)
	Recommended	0.0728 (0.0086)	0.09079 (0.0093)	0.0794 (0.0102)	0.0821 (0.0083)	0.0809 (0.0079)	0.0628 (0.0090)	0.0621 (0.0073)	0.2972 (0.0375)	0.5309 (0.0594)
	Difference	-0.0006	0.0003	-0.0017	0.0012	0.0013	-0.0004	0.0002	-0.0026	0.0003
2	Current	0.0711 (0.0113)	0.0878 (0.0143)	0.0775 (0.0123)	0.0817 (0.0119)	0.0808 (0.0122)	0.0618 (0.0093)	0.0614 (0.0098)	0.2895 (0.0461)	0.5221 (0.0799)
	Recommended	0.0707 (0.0115)	0.0891 (0.0165)	0.0766 (0.0115)	0.0802* (0.0121)	0.0791* (0.0114)	0.0608 (0.0100	0.0608 (0.0096)	0.2905 (0.0457)	0.5174* (0.0814)
	Difference	0.0004	-0.0013	0.0009	0.0014	0.0016	0.0009	0.0006	-0.0010	0.0047
3	Current	0.0700 (0.0135)	0.0863 (0.0146)	0.0764 (0.0124)	0.0803 (0.0144)	0.0805 (0.0151)	0.0608 (0.0103)	0.0602 (0.0098)	0.2870 (0.0497)	0.5146 (0.0887)
	Recommended	0.0700 (0.0128)	0.0863 (0.0145)	0.0764 (0.0137)	0.0795 (0.0136)	0.0793 (0.0136)	0.0601 (0.0107)	0.0598 (0.0104)	0.2837 (0.0484)	0.5114 (0.0881)
	Difference	2.41E-05	5.62E-06	-9.9E-06	0.0008	0.0013	0.0007	0.0004	0.0033	0.0032
2 or 3	Current	0.0706 (0.0122)	0.0871 (0.0143)	0.0770 (0.0121)	0.0810 (0.0130)	0.0806 (0.0135)	0.0613 (0.0097)	0.0608 (0.0096)	0.2883 (0.0471)	0.5184 (0.0831)
	Recommended	0.0704 (0.0120)	0.0877 (0.0154	0.0765 (0.0124)	0.0799* (0.0126)	0.0792* (0.0123)	0.0604* (0.0102)	0.0603 (0.0098)	0.2872 (0.0464)	0.5145* (0.0834
	Difference	0.0002	-0.0007	0.0005	0.0011	0.0014	0.0008	0.0005	0.0011	0.0039

Note. Negative values (-) in the difference rows indicates that the time for the recommended condition were slower than the current condition.

* Recommended was significantly faster than current ($p < .05$).

Table 30

Questionnaire response frequency

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<tr><td>Q7</td><td colspan="2">1</td><td colspan="2">6</td><td colspan="2">9</td><td colspan="2">20</td><td colspan="2">4</td></tr>
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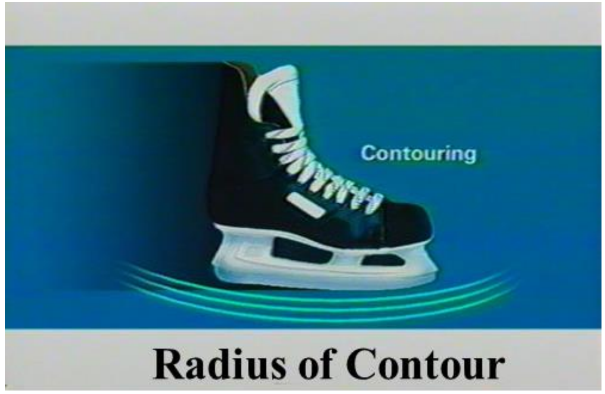

Figure 1. Radius of contour (ROC). Photo taken from Lockwood & Winchester (2004).

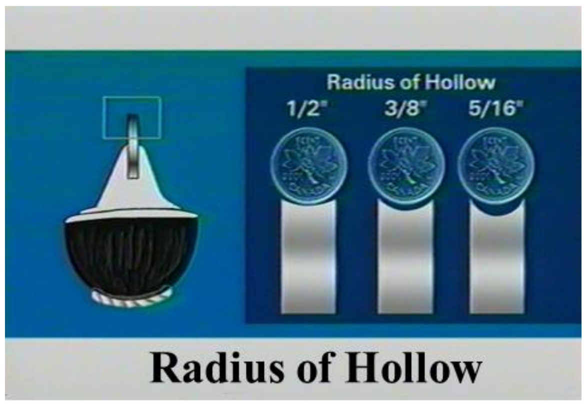

Figure 2. Radius of hollow (ROH). Photo taken from Lockwood & Winchester (2004).

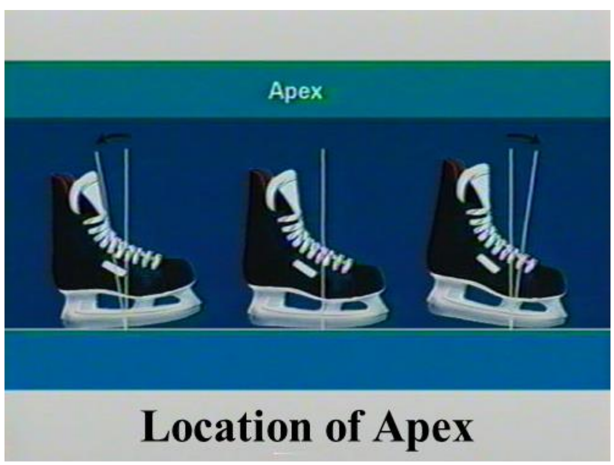

Figure 3. Pitch (P). Photo taken from Lockwood & Winchester (2004).

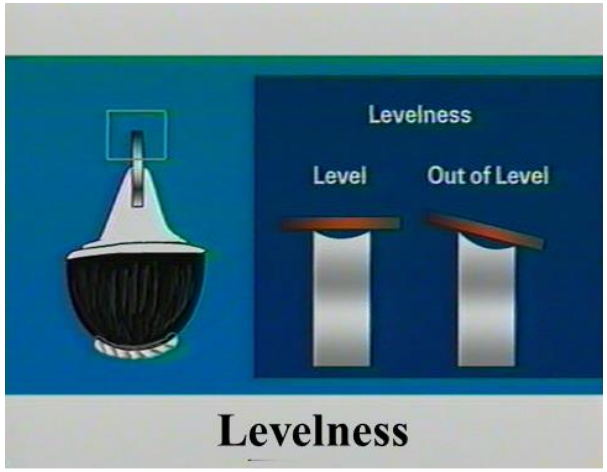

Figure 4. Edge levelness (EL). Photo taken from Lockwood & Winchester (2004).

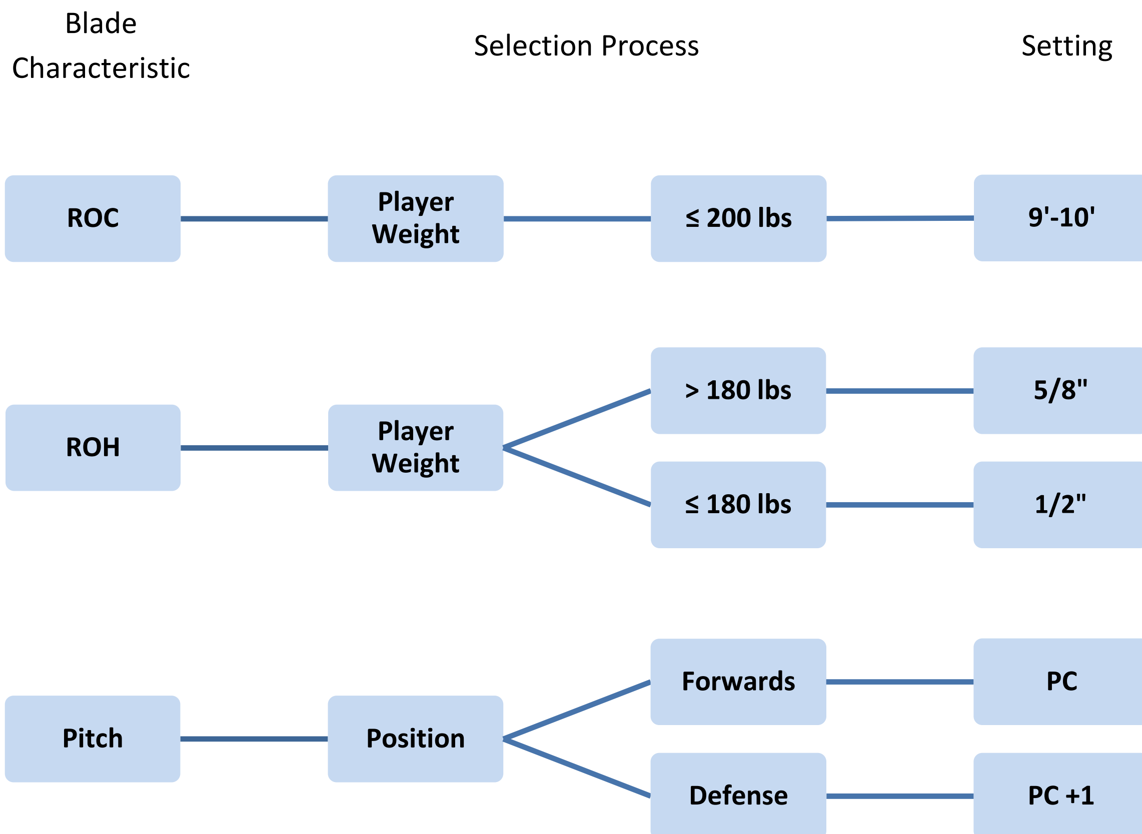

Figure 5. Selection model for recommended blade characteristics.

Glossary of Terms

Apex: The pivot point, or high point, of the skate blade.

Balance point (BP): The point on the skate blade through which the skater's weight is focused.

Bite angle: The angle created between the interior of the skate blade edge and the ice surface. Larger bite angles will cause the blade to penetrate the ice further while smaller angles will cause the blade to penetrate the ice less.

Blade center (BC): The center of the skate blade as measured from heel to toe of the blade.

Center of mass (COM): A singular point where the total mass of an object can be said to be acting.

Edge levelness: The height of the two edges of a skate blade relative to one another. Edges within 1/1000th of an inch are typically considered level within the skate sharpening discipline.

Pitch: Also often referred to as lie, pitch is use to describe the angle of the skate relative to the ice surface.

Pitch center (PC): A point on a skate blade positioned slightly closer to the heel of the blade then BC.

Radius of contour (ROC): Commonly referred to as blade profile, it represents the longitudinal curvature of the blade. ROCs are offered in single contours, consisting of a single radius along the length of the blade, double contours consisting of two radii along the length of the blade, and triple contours, involving a double contour where the two radii are blended together with a flat section in the blade.

Radius of hollow (ROH): Refers to the depth of the groove on the base of the blade that is applied during the sharpening process.

Relief angle: The angle created between the side of a skate blade and the surface of the ice.

Appendix A: Mathematical Models

Mathematical Model 1

$$XCOM = Sin(\theta) \times h$$

Where:

XCOM = the shift in COM in the anterior posterior direction from a neutral pitch

θ = the change in angle created by the pitch

h = The height of COM

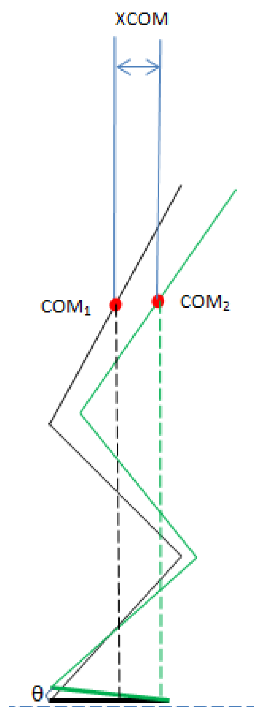

Figure 6. Shift in COM (XCOM) caused by a pitch of theta, when all internal angles are held constant.

Mathematical Model 2

Equation 1 (Broadbent, 1985):

$$Xbp = \frac{h}{r - h} \times Xa$$

Where:

Xbp = The shift in balance point from blade center
Xa = The shift in apex from blade center
h = The height of COM
r = ROC

Equation 2:

$$\Delta\theta = (\Delta X / 2\Pi r) \times 360°$$

Where:

ΔX = The distance between apex and balance point (Xbp + Xa)
Δθ = The angle change in the lie of the skate
r = ROC

Height difference in blade caused by shit in apex:

$$h = l \times Sin\,(\theta)$$

Where:

h = height difference
θ = Angle change in lie of the skate
l = blade length

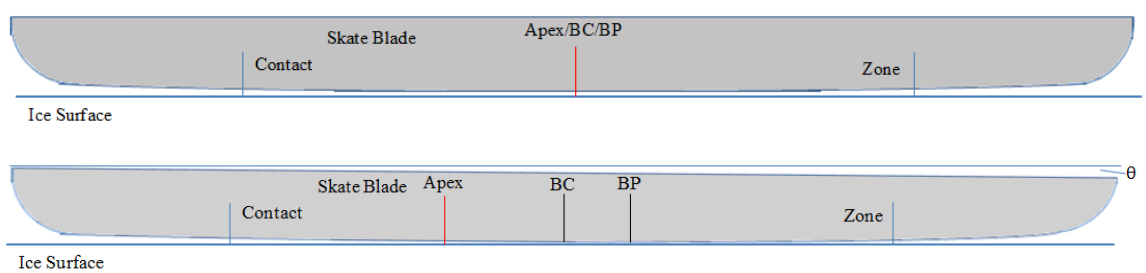

*Figure 7.*Top: skate blade with neutral pitch consisting of a center apex and BP on a 9 ft ROC. Bottom: change in lie (angle θ) and forward shift in BP created a 1” backwards shift in blade apex on a 9 ft ROC.

Appendix B: Player & Skate Demographics Form

Player Information/Anthropometrics:

Player ID (Number):____________________ Position:________________________

Current Team/Level of Play:____

Age:_____________________ Years of hockey experience:____________________

Height:__________________ Weight:________________________

Skate Information:

Skate brand/model:____

Blade holder brand/model:__________________________________Size:______________

Blade brand/model:____

Appendix C: Blade Sharpening Characteristics

Player ID (Number):

	Radius of Contour	Radius of Hollow			Pitch		Edge Levelness
		25%	50%	75%	Toe	Heel	
Right skate							
Left skate							
Recommended							

Appendix D: Participant Feedback Questionnaire

Ice session:

Player ID (Number):

Please circle your answers to the following questions on the scale of 1-5

1 = Strongly Disagree
2 = Disagree
3 = Neither Agree or Disagree
4 = Agree
5 = Strongly Agree

1) I felt that the recommended sharpening characteristics allowed me to turn tighter in comparison to my current sharpening characteristics.

   1 2 3 4 5

2) I felt that the recommended sharpening characteristics allowed me to skate faster in comparison to my current sharpening characteristics.

   1 2 3 4 5

3) I felt that the recommended sharpening characteristics glided across the ice better in comparison to my current sharpening characteristics.

   1 2 3 4 5

4) I felt that the recommended sharpening characteristics had a stronger grip on the ice in comparison to my current sharpening characteristics.

   1 2 3 4 5

5) I felt that the recommended sharpening characteristics allowed me to skate faster backwards in comparison to my current sharpening characteristics.

   1 2 3 4 5

6) I feel more confident in my skating abilities on the recommended sharpening characteristics in comparison to my current sharpening characteristics.

   1 2 3 4 5

7) I prefer how the recommended sharpening characteristics felt in comparison to my current sharpening characteristics.

1	2	3	4	5

8) Rate your skating effort during today's testing session.

1	2	3	4	5	6	7	8	9	10

Appendix E: Description of Skating Drills

Forwards skating drill: Players positioned themselves on the starting line with both feet facing forwards and their toes on the line. When the timing light signaled them to start they skated forward as fast as possible until they reached the far blue line.

Backwards skating drill: Players positioned themselves on the starting line in a backwards position, with their heels on the line. When the timing light signaled them to start the drill they accelerated off the start line, skating backwards as fast as they could until they crossed the far blue line.

Agility skating drill: Players positioned themselves at the starting line with both feet facing forwards and their toes on the line. When the timing light signaled them to start they skated as fast as they could through a series of pylons, performing one cross over step between each pylon.

Stops and starts to the right: Players started facing to the right, with their left foot on the start line. When the timing light signaled them to start they skated as fast as possible to the near blue line where they stopped facing to the right with both feet crossing over the blue line. They then proceeded to skate as fast as possible back to the start line.

Stops and starts to the left: Players started facing to the left, with their right foot on the start line. When the timing light signaled them to start they skated as fast as possible to the near blue line where they stopped facing to the left with both feet crossing over the blue line. They then proceeded to skate as fast as possible back to the start line.

Crossovers: Players started at the outside hash marks of an end zone circle facing left toward the near boards. When the timing light signaled them to start they skated around the bottom of the circle and back up through the center passing the inside hash marks.

They continued to the outside hash marks of the opposite circle and stop facing the boards. A second timing light then signaled them to start and the player proceeded with the same cross over drill in the opposite direction.

Combined skills skating drill: Players positioned themselves on the goal line with both feet facing forwards and their toes on the line. They started by skating forwards to the near blue line where they transitioned to backwards skating. Backwards skating was continued between the two blue lines, when the far blue line was reached, players transitioned back to forwards skating and continue to the far goal line. At the far goal line players executed a tight turn and proceeded through an agility skating section set up with pylons. When players exited the agility skating section they then finished the drill by skating forwards to the starting goal line.